MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AD A124734
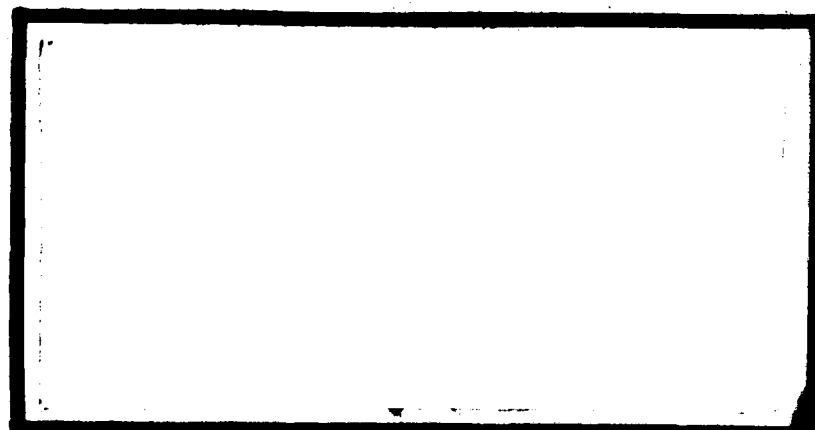
DTIC
S ELECTE
FEB 2 2 1983
A

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY (ATC)
AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

83   02   022 158

DTIC
COPY
INSPECTED
2

AN EVALUATION OF THE EFFECTIVENESS OF
DEPLOYING ELECTRO-OPTICAL TELESCOPES
FOR SATELLITE TRACKING ON HIGH
ALTITUDE POWERED PLATFORMS

THESIS

Richard T. Salmon
Capt.   USAF
AFIT/GSO/██/82D — 4
OS'

DTIC
SELECTED
FEB 2 2 1983

A

AN EVALUATION OF THE EFFECTIVENESS OF

DEPLOYING ELECTRO-OPTICAL SATELLITE

TRACKING TELESCOPES ON HIGH ALTITUDE

ALTITUDE POWERED PLATFORMS

THESIS

Presented to the Faculty of the School of Engineering

of the Air Force Institute of Technology

Air University

in Partial Fulfillment of the

Requirement for the Degree of

Master of Science

by

Richard T. Salmon

Capt.   USAF

Graduate Space Operations

December 1982

Preface

This research was performed to determine the potential of
developing electro-optical satellite tracking telescopes on board
high altitude powered platforms. A computerized simulation model was
developed to conduct a comparative analysis of a hypothetical system
of air based telescopes with the Ground-Based Electro-Optical Deep
Space Surveillance (GEODSS) System. Some effort was also devoted to
assessing the feasibility of an air based satellite tracking telescope.

Thanks go to Professor Edward Dunne for his guidance in the
analysis procedures, Professor James Lange for his assistance in
electro-optics, and Capt. Charles Ruberson for his help in obtaining
cloud cover data.

<div align="right">Richard T. Salmon</div>

Contents

List of Figures

List of Tables

Abstract

The purpose of this research was to evaluate the possible benefits of an air based system of electro-optical satellite tracking telescopes. A computerized simulation model was developed to conduct a comparative analysis of a hypothetical system of air based telescopes with the Ground-Based Electro-Optical Deep Space Surveillance (GEODSS) System. The simulation includes a first order optimization process for selecting a satellite surveillance system and a many-on-many engagement model to test the effectiveness of the surveillance system selected. In addition, the user can input a preselected surveillance system and test its effectiveness.

The user specifies the characteristics of the surveillance system and the basing locations, if they are preselected. Cloud cover data can be entered with preselected ground sites. Target satellites included four sets of representative satellite systems. The user selects the targets, defines the mission time, and determines the percentage of each target system which must be tracked.

Preliminary results indicate that an air based surveillance system with three dispersed telescope platforms could outperform a system of five candidate GEODSS sites.

AN EVALUATION OF THE EFFECTIVENESS OF DEPLOYING ELECTRO-OPTICAL TELESCOPES FOR SATELLITE TRACKING ON HIGH ALTITUDE POWERED PLATFORMS

I   Introduction

Background

Optical sensors provide an important input to the Space Detection and Tracking System (SPADATS), a network of sensors maintained by the Air Force to monitor all man-made objects in space (Ref 1:Ch 2). Unlike radar, optical sensors can with relative ease track a satellite in deep space. The Baker-Nunn camera, classified as a modified Schmidt telescope, is currently SPADATS' primary deep space sensor. This telescope can track an object the size of a basketball at 35,000 nautical miles (Ref 1:Ch 2, 20).

Unfortunately, the presence of the atmosphere limits the utility of these sensors. The atmosphere limits telescopes in five ways (Ref 1:Ch 5, 31-32). The first limitation is due to weather. Clouds, fog, and rain severely degrade atomospheric transmission. The second limitation is that the atmosphere is not transparent to all regions of the electromagnetic spectrum. The atmosphere is actually opaque in some regions of the spectrum. The third problem is that the atmosphere scatters light. Thus an astronomical telescope cannot detect faint objects in daylight, and at night even city lights limit the depth that can be probed by a telescope. The fourth problem is caused by variations in the density of the atmosphere. It is these variations which cause the stars to twinkle. Finally, the fifth limitation is that under s____.

conditions the atmosphere can emit light. The auroras illustrate this ability. As a result of these limitations, it is desirable to locate optical telescopes at remote sites at high altitudes. This creates severe complications in choosing sites for SPADATS' optical sensors.

Airborne electro-optical telescopes have been proposed as a means of circumventing some of the atmospheric limitations. In 1967, Nortronics (Palos Verdes Peninsula, California) conducted a design study for an airborne electro-optical surveillance system (Ref 2). Since then, the feasibility of using airborne optical sensors for satellite tracking has been demonstrated. In 1970, a long-wavelength infrared search/track radiometer, mounted on a U-2 aircraft, successfully acquired and tracked Pegasus satellites up to a range of 720 nautical miles (Ref 3:81-94).

Most experience with airborne optical sensors has been gained by astronomers using infrared telescopes. Because the atmosphere absorbs infrared radiation, celestial observations from the earth's surface are limited to views from high altitudes through narrow "atmospheric windows" at 1 to 2.5, 3 to 5, 8 to 12, 20, and less clearly at 350 microns (Ref 4). At sea level, most atmospheric absorption of the infrared is due to water vapor and carbon dioxide; however, the water content of the atmosphere decreases rapidly with altitude, and above 40,000 feet, the water content of the air is negligible (Ref 5:118). The two types of vehicles which astronomers have used most successfully as airborne observatories are balloons and airplanes. The balloon has the advantage of high operating altitudes. For example, a 40-inch far-infrared telescope has been carried to 95,000 feet several times by balloon (Ref 6), and the NASA Ames Research Center has sent a

2

balloon-borne 28-inch telescope to 100,000 feet (Ref 4). The Ames Center also operates a Learjet carrying a 12-inch telescope and a C-141 carrying a 36-inch telescope (Ref 7). Although these aircraft can operate only up to 45,000 feet, they can carry equipment operators in a shirt sleeve environment, the flight path is controlled, and the payload is not at risk. In addition, the C-141 can carry a large payload.

But neither the balloon nor the airplane are practical for satellite surveillance (Ref 8:Sec B.2). Balloons have little station-keeping ability. This imposes a serious constraint since sensor data must be sent to the ground where it can be processed. Airplanes, on the other hand, would be too expensive. Due to expected aircraft availability, at least three planes would be required at each station to assure 16 hours/day operation.

A third kind of high altitude sensor platform is still under development. Both the Air Force (Ref 9) and the Navy (Ref 10) have sponsored programs for the development of an unmanned high altitude airship (or aerostat).

This concept combines some of the advantages of the airplane and the free balloon since the vehicle should be able to maintain a stationary position above the ground at 70,000 feet. The Air Force sponsored program has demonstrated that such an airship can be built. In May of 1970, High Platform II, a solar powered airship, was flown. This vehicle had a design speed of 10.3 meters/seconds at 20 kilometers above sea level. In spite of two attempts, the Navy has not yet sponsored a successful flight, but their effort is perhaps more ambitious. The Navy's High Altitude Superpressured Powered Aerostat

3

(HASPA) program has built an ship which is designed to maintain a payload of 4,000 pounds at 70,000 feet for 1 year.

The development of a practical high altitude airship has been slowed by two serious problems (Ref 11). The most serious of these problems is developing a suitable hull fabric. The high operating altitudes impose a severe strength to weight ratio requirement. Materials exist which can meet this requirement; but finding a material which also resists abrasion, tolerates temperature extremes, and tolerates ultraviolet light is a problem. The second problem is that the high altitude airship requires a lightweight power system for payload operation and propulsion. Several types of power systems are being studied as alternatives. Perhaps the most probable candidate for long duration flights is a regenerative power source utilizing solar arrays (Ref 11). However, NASA is evaluating the feasibility of powering an aerostat or even an unmanned lightweight airplane with a microwave power system (Ref 12). This should also be suitable for long duration flights. For short duration flights, up to 30 days or more, technology is currently available to assemble a gasoline fueled, turbocharged, reciprocating engine capable of providing sufficient power (Ref 13).

The latest effort to build a practical high altitude airship is a concept called Hi-Spot for high altitude surveillance platform for over-the-horizon targeting (Ref 14). Hi-Spot could hover at 60,000 to 80,000 feet for as long as 155 days. It would be 504 feet long and 154 feet in diameter, would carry a 550-pound payload, and would be propelled by a 27 meter diameter propeller powered by a hydrogen fueled, air breathing engine(s). The Hi-Spot concept is being studied for the

4

Navy by Lockheed Missile & Space Company for applications including air/sea surveillance, communications relay, remote sensors readout, and signal intelligence (SIGENT) collection missions. The Lockheed design is being considered for a Fiscal 1984 start of a technical risk reduction program and scale model demonstration.

Objective of the Study

In the past (Ref 8:Sec B.2), the high altitude airship has been summarily dismissed as a viable platform option for satellite surveillance because of the relatively high development risk associated with finding a suitable hull fabric and because of the limited station-keeping ability of the proposed designs. However, interest in developing a high altitude airship has continued, and Hi-Spot may soon demonstrate the feasibility of such a vehicle. Furthermore, NASA is now investigating the feasibility of a High Altitude Powered Platform (HAPP) which would be either an unmanned airship or airplane utilizing a microwave power system. The results of their cost/feasibility study appear promising (Ref 15). In addition, NASA has funded user surveys in various areas of application (Ref 16). These surveys suggest that the HAPP system would have the attributes of a low attitude geostationary satellite. It would be particularly useful as a communications relay, and it would also be attractive in some remote sensing applications where very frequent coverage is required.

Since the implementation of a high altitude airship concept in some form appears likely, the practical value of an aerostat for satellite surveillance should be reassessed. The first step in that process should be to determine what practical value the aerostat would

5

have in operational terms. The problem of interest here is to estimate
the effectiveness of a system of airship-based optical sensors
in performing the deep space surveillance mission and to compare this
to a system of ground-based sensors. Thus the objective of this study
is to assess the gain in mission performance due to three major
operational advantages conferred by the airship:

1. The optical sensor would be relatively insensitive to weather
   limitations.

2. The optical sensor could be stationed almost anywhere.

3. The infrared portion of the spectrum would be more readily
   available to the sensor.

Modeling Approach

The comparison between the different modes of sensor basing, airship
versus ground basing, can be made by using a computer program derived
from HELBASE, a computer simulation model for the investigation of high
energy laser applications in the antisatellite role (Refs 17 and 18).
The purpose of HELBASE is (given specific mission requirements) to
determine the optimal configuration and number of laser weapons re-
quired to "shoot" a given number of satellites with a given probability
of success. The program can make these selections regardless of
whether the laser weapons are ground-, air-, or spacebased. To deter-
mine if a particular system design (number and location of weapons)
will meet the mission requirements, the program simulates several
battles. If the system is unsatisfactory, the program selects the next
"best" weapon/location combination to add to the system. This ensures
that the weapons system selected can meet the mission requirements.

6

Obviously HELBASE needed to be adapted for this thesis. HELBASE has been revised to do the following:

1. Allow the input of selected ground sites with predefined coordinates (latitude, longitude, and altitude) and associated sky cover probabilities.

2. Account for the effect of weather on a ground-based sensor's performance by utilizing sky cover probabilities in Markov chain model.

3. Determine if a target satellite can be tracked based upon the sun/earth shadow, target, and sensor configuration as well as the type of sensor involved.

The output from the model is the average time required to track all of the simulated target satellites. For this study, target satellite orbits were selected which emphasized the ability to detect and track injections from parking orbits into highly elliptical, 12-hour orbits and to detect maneuvers.

Scope, Limitations, and Assumptions

Scope. This effort is limited to comparing the performance of the aerostat-based versus ground-based optical sensors in the role of deep space surveillance and tracking. No comparison of investment and operating costs has been made. The ground-based system against which the aerostat-based system was compared was the Ground-Based Electro-Optical Deep Space Surveillance (GEODSS) system which is now in the process of being deployed.

Limitations and Assumptions. Since there has been only moderate interest, an aerostat-based electro-optical telescope has yet to be built that could meet the requirements for deep space satellite

surveillance. It is somewhat uncertain how such a system would perform. For the purposes of this study, however, it has been assumed that an aerostat based electro-optical telescope can track objects in geosynchronous orbit and that the expected problems with pointing accuracy, position fixing, and weight limits can be overcome at a reasonable cost.

Sites for the aerostat-based system were selected from 13 evenly spaced latitudes from 60 degrees north through 60 degrees south. No other limits were placed upon deployment. This is somewhat unrealistic, however, it is possible that configuration of the aerostat-based systems could be approximated in the real world. The aerostat based optical sensors were assumed to be operating at 70,000 feet and without weather interference. Sites for the ground-based system were placed in the same configuration as those sites selected for the GEODSS system. The sky cover (weather interference) for each of the ground sites was estimated using a model which assumed that the sky cover conditions persisted for at least a 3-hour interval.

The orbital mechanics used in the model assume a simple two body problem with the satellites acting as point masses. The Earth is regarded as a simple sphere of radius 6378.145 kilometers.

Sequence of Presentation

Chapter II provides an overview of the computer simulation model. In addition, some of the basic physical principles used in the model are described. Chapter III contains an explanation of the concepts employed in each of the model's subprograms. Chapter IV gives the results of the basing mode analysis. Chapter V, the conclusion, includes a summary of this thesis, some conclusions derived from this work, and recommendations for further study.

8

II Model Overview

This chapter presents a general overview of the program EOBASE. The user inputs, the submodels, and some of the basic physical principles which are used in the program are described. The program EOBASE was derived from HELBASE (Refs 17 and 18), and it is analogous to HELBASE in as much as one of its purposes is to select "the most efficient" sensor system. However, EOBASE can also be used to evaluate a system of sensors with user selected sites.

Definition of Terms

1. Basing Mode: This refers to the possible sensor locations. The three alternative locations are the surface of the earth, in an aircraft or aerostat, and in a circular orbit around the earth.

2. Sensor: One electro-optical sensor which either detects visible or infrared radiation from a specific sensor type.

3. Sensor Type: A specific combination of specific electro-optical sensor characteristics.

4. Sensor System: A collection of sensors selected from the available sensor types.

5. Target: A single specific satellite which a sensor may track.

6. Target Type: A group of targets which are related by a common set of mission and orbital parameters.

7. Target System: The collection of all selected targets.

8. Mission: The operational capabilities around which the sensor system is to be defined.

9. Most Efficient: Like HELBASE, EOBASE selects a system which is a first cut approximation of the optimal system. The term "most efficient" is viewed in this sense.

User Inputs

The EOBASE program allows the user two distinct options. The program can be used to select the most efficient sensor system, or it can be used to evaluate a user selected system. Each of these options requires somewhat different input formats. Appendix A illustrates these input formats and provides a description of the various inputs.

However the user chooses to use the program, the following categories of user inputs are required: general, sensor types, target types, and mission data. Table I provides a summary of these inputs.

Up to five sensor types may be input. As illustrated in Table I, both the basing mode and the sensor characteristics are needed to specify a sensor type. One of three basing modes can be chosen for each sensor type, the ground mode, the air mode, or the space basing mode. If the user elects to have the EOBASE program select the sensor system; selection of the ground mode, Mode 1, limits deployment to the latitudes on the surface of the earth; selection of the air mode, Mode 2, limits deployment 21.3 kilometers above latitudes on the surface of the earth; and selection of the space basing mode, Mode 3,

10

TABLE I

User Inputs: General, Sensor Data, and Mission Data

Input Category	Variable	Dimension
General	SEED	—*
	JCOUNT	—
	NOWT	—
	ICOUNT	—
	DT	Minutes
	P	—
	INPUT	—
	INPUTS	—
	SUNTYP	—
Sensor Data	Basing mode	—
	Sensor	—
	Cutoff/angular resolution	Visual magnitudes/steradians
	Altitude	Kilometers
	Minimum tracking time per cycle	Seconds
	Dwell time	Seconds
Target Type Selection	Del	—
Mission Data	Target type	—
	Target type tracking percentage	—
	Mission time	Minutes
	Target type tracking priority	—

*Dimensionless parameter.
 Note: Several sets of sensor and/or mission data are possible.

limits deployment to circular orbits around the earth at an altitude
specified by the user.

The EOBASE program provides the user with the selection of any
combination of four target types. These target types are permanently
stored in EOBASE, and they are intended to be reasonable
representations of real world target possibilities. See Table II for
a description of the four types.

TABLE II

Target Type Descriptions

Target Type	I	II	III	IV
Semimajor axis (kilometers)	22,260.0	22,260.0	42,164.0	42,165.0
Orbital eccentricity (dimensionless)	.7	.7	0	0
Orbital inclination (radians)	1.1340	.7854	1.5708	0
Argument of perigee (radians)	4.0143	4.5379	0	0
Longitude of the ascending node (radians)	Random*	Random	Random	0
Mean anomaly	Random*	Random	Random	Random
Number of targets	3	4	3	4

*Each set of targets is evenly spaced over 360 degrees.

A set of mission data inputs must be provided by the user with each target type selection. These inputs define the minimum mission requirements for tracking each type of target, and they are particularly relevant when EOBASE is used to select the most efficient sensor system. The target type tracking percentage is the percentage of a particular type of target which must be tracked to ensure mission accomplishment. The mission time is the maximum time a selected sensor system is allowed to accomplish the mission. This input must be the

12

same for all target types. A target type tracking priority is assigned to each target type (one is the highest). The tracking priority is used to determine which target is tracked first if two targets can be tracked at the same time. A secondary criterion is the target's range from the sensor. The target with the shortest range, within a particular priority group, is tracked first.

A fifth input category, ground site locations, is used when the user wishes to input previously selected sites for sensors in the ground mode. As shown in Table III, the user enters the latitude, longitude, altitude, and sensor type of each ground-based sensor. Associated with each of these site locations is a sixth input

TABLE III

User Inputs: Ground Site Locations and Air and Space

Based Sensor Location Parameters

Input Category	Variable	Dimension
Ground site locations	Latitude	Radians
	Longitude	Radians
	Altitude	Kilometers
	Sensor type	---*
Sky cover probabilities (see Table IV)	Conditional	---
	Unconditional	---
Air and space-based sensor location parameters	Orbital radius or coordinate theta	Kilometers or radians
	Eccentricity	---
	Inclination or coordinate theta	Radians or radians
	Longitude of ascending node	Random
	Argument of perigee	0

*Dimensionless parameter

TABLE IV

User Inputs: Sky Cover Probabilities

Initial Time	Starting Condition	Array # 0 hours	Array # +3 hours	Array # +6 hours	Array # +9 hours	Array # +12 hours
1700 L	0-3/8	1	2	4	6	8
	4-8/8		3	5	7	9
2000 L	0-3/8	10	11	13	15	
	4-8/8		12	14	16	
2300 L	0-3/8	17	18	20		
	4-8/8		19	21		
0200 L	0-3/8	22	23			
	4-8/8		24			
0500 L	0-3/8	25				
	4-8/8					

category, sky cover probabilities. These are the probabilities for the occurrence of less than or equal to 3/8 total cloud cover. These probabilities are used to determine whether or not the sensor has a cloud free line of sight. As shown in Table IV, the sky cover probabilities for each site are inserted into an array which requires 25 inputs for each site. The probabilities are used to simulate cloud cover conditions from 1700 hours to 0700 hours local time. The input values under the 0 hours column are the unconditional probabilities of less than or equal to 3/8 sky cover at the initial time. The remaining

14

inputs are the conditional probabilities of less than or equal to 3/8 sky cover given the initial sky cover condition and starting time.

Finally, the seventh input category is the air-and space-based sensor location parameters. These inputs are used if the user wishes to evaluate a user selected sensor system which includes air-or space-based sensors. As shown in Table III, there are six inputs in this category. These include the sensor type and the orbital parameters for a space-based sensor or the latitude (coordinate theta) for an air-based sensor.

Basic Physical Principles

The fundamental aspects of orbital mechanics and sensor operation as used in EOBASE are described below.

Orbital Mechanics. The EOBASE program employs the same techniques and principles of orbital mechanics as utilized in the HELBASE simulation (Refs 17 and 18). As stated in Chapter I as an assumption, the techniques used here assume a simple two body problem with the satellite acting as a point mass, and the earth is regarded as a simple sphere of radius 6378.145 kilometers.

The coordinate reference system employed in the model is the geocentric-equatorial system. This system has its origin at the earth's center, and it is essentially fixed with respect to the stars. Figure 1 depicts this reference system.

Sensor Operation. Both of the two classes of electro-optical sensors which can be evaluated with EOBASE have to have two conditions satisfied before they can be used for satellite tracking. First, the sensors have to be located either in space or on the night side of the

15
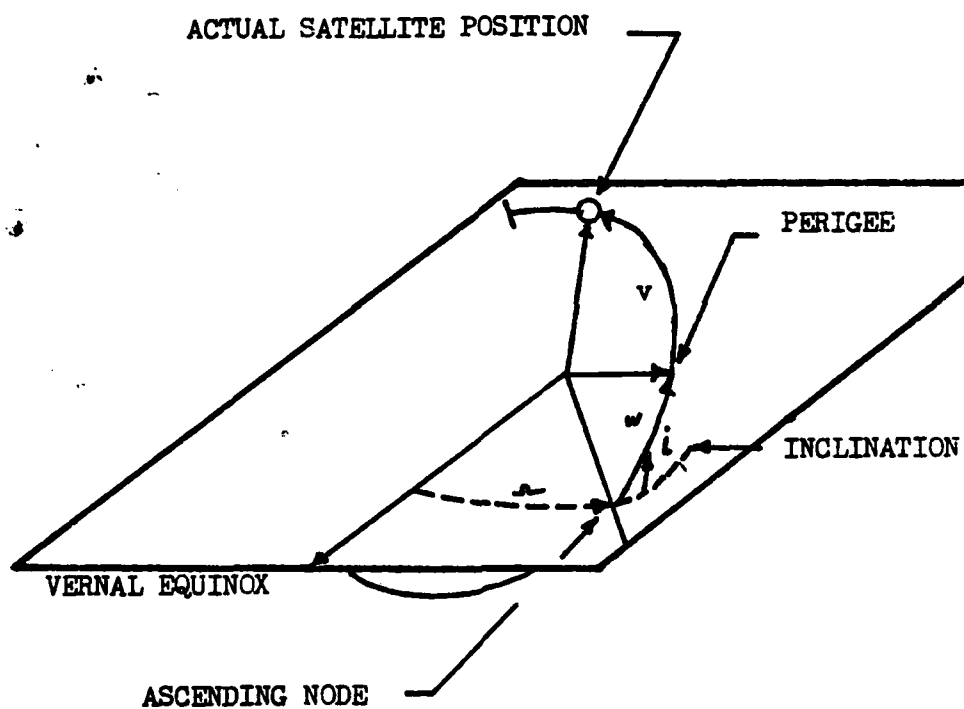
Figure 1.   Geocentric equitorial reference.

16

clear line of sight to the target. Second, the sensor cannot operate in the presence of cloud cover or with the earth between it and its target.

Once these preconditions have been satisfied, the differences between the sensors become important. The sensor class of primary interest here (like the GEODSS system) uses the sunlight reflected by the target satellites to detect them. The amount of sunlight which the targets reflect is dependent upon the relative positions of the sun, the target, and the sensor. This relationship is illustrated in Figure 2. For the sake of simplicity, all of the targets in the EOBASE simulation are modeled as cylinders with an earth center orientation. In addition, the irradiance of the sun (Ho) is assumed to be constant throughout the orbits of the target satellites. In this case, the irradiance of the light reflected by the target at the sensor can be calculated if the following is known (Ref 19:12, 15, and 84-86): the distance between the target and the sensor (R), the sensor aspect angle (α), the solar aspect angle (β), the phase angle (ϕ), the reflectivity of the cylinder (ρc) and the endplate (ρp), and the projected area of the cylinder (Ac) and the endplate (Ap). The following formulas are employed.

$$Hp = \frac{Ho\ \rho p\ Ap\ \cos\alpha\ \cos\beta}{\pi\ R^2}$$

$$Hc = \frac{Ho\ \rho\ Ac\ \sin\alpha\ \sin\beta\ (\sin\theta + [\pi - \theta]\ \cos\theta)}{4\ \pi\ R^2}$$

17
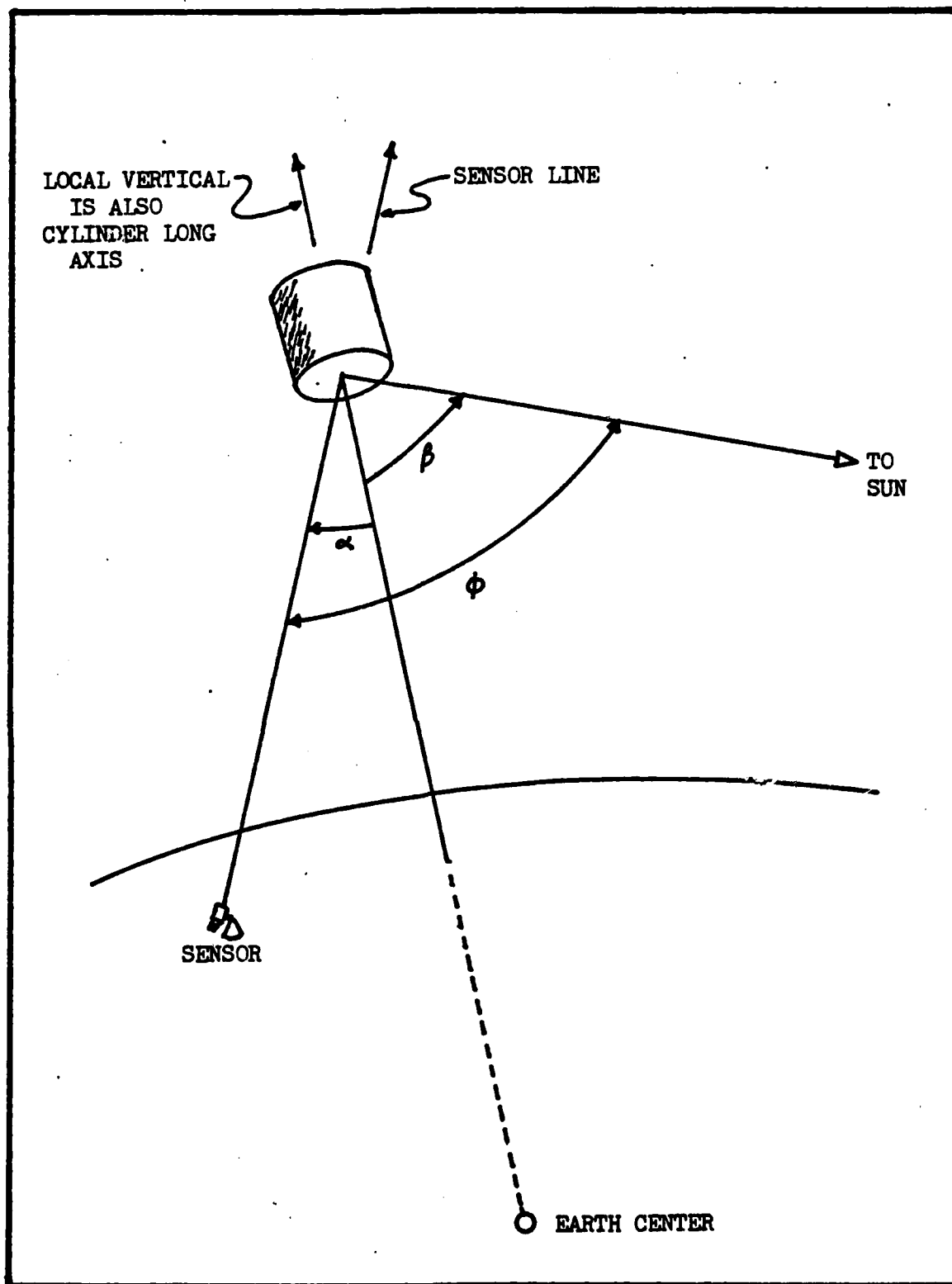
Figure 2. Sunlight reflection geometry.

18

where

    Hp = the irradiance at the sensor due to the end plate

    Hc = the irradiance at the sensor due to the cylinder

    $\theta = \cos^{-1} (\cos \phi - \cos \alpha \cos \beta \sin \alpha \sin \beta)$

The final value is computed in units of visual magnitudes of light.

$$MAG = M_{v\bullet} - 2.5 \log_{10} \left[\frac{Hp + Hc}{Ho} \right]$$

where

    MAG = the visual magnitude of the target at the sensor

         number

    $M_{v\bullet}$ = the visual magnitude of the sun at the target

         $= -26.78 \; M_v$

The visual magnitude of light from the target can then be compared with the amount of light that the sensor needs to detect the target. If the number is low enough (the smaller the number the more light), then the sensor can detect the target.

The second sensor which can be considered using EOBASE detects satellites from their thermal emissions in the long wavelength infrared (LWIR) range of 8 to 14 micrometers. Unlike the reflected sunlight employed by the previous sensor, the emissions come directly from the satellite itself, and their intensity and wavelength are primarily

19

dependent upon the temperature of the satellite. The emissions can be modeled using Planck's Blackbody Radiation Law (Ref 20:Ch 1).

As indicated in Chapter I in the introduction, some experimental work has been done with this kind of sensor using a U-2 aircraft (Ref 3). However, the sensitivity of this system was not great enough to detect deep space satellites (Ref 3:Ch 3). The system ultimately was limited by background infrared emissions from the atmosphere and the telescope itself. Nonetheless, this type of sensor has been included as an EOBASE sensor option since it is conceivable that further improvements in detector technology could make it feasible to use it for deep space satellite tracking. Such a breakthrough, the development of the vidicon imaging tube, has been extremely important in the development of visible wavelength sensors for satellite tracking (Ref 21). The extremely small image cell diameters or detector spot sizes which can be achieved with these tubes are to a great extent responsible for the high sensitivity of the GEODSS system.

So, the long-wavelength infrared sensor is included in EOBASE with two assumptions. First, the sensor will be either in a space-based or air-based mode. The ground-based mode will be excluded because of the relatively much higher sky background at lower altitudes and because the presence of water vapor prohibits cooling the optics to liquid nitrogen temperatures. Second, it will be assumed that the sensor has sufficient sensitivity to track target satellites in geosynchronous orbits in a reasonable time frame.

Because of the effect that the earth's atmospheric radiance has upon the LWIR Air-Based Sensor, an effort has been made to have EOBASE account for the loss of sensitivity as the zenith angle increases with

20

respect to the sensor's line of sight to the target satellite. Therefore, EOBASE calculates the irradiance at the sensor due to both the target satellite and the atmosphere. The formula used to determine the irradiance at the sensor (ε_T) from the target is based upon the point source approximation (Ref 22:App 5)

$$\varepsilon_T = \frac{L\lambda\ (\overline{\lambda})\ a^2\ \tau A\ \Delta\lambda}{r^2}$$

where

$L\lambda_T\ (\overline{\lambda})$ = the radiance of the target at the middle of the sensor's spectral band

a = the radius of the target

τ_A = the average atmospheric transmittance

$\Delta\lambda$ = the bandwidth of the sensor

r = slant range to the target

The irradiance at the sensor on a single detector field of view due to the atmosphere (ε_β) is calculated by (Ref 20):

$$\varepsilon_\beta = \Omega_1\ L\lambda_A\ \tau A$$

where

Ω_1 = the field of view of a single detector

$L\lambda_A$ = the radiance of the atmosphere over the spectral band of the sensor

Once the irradiance at the sensor is known, the current response both due to the target irradiance and due to the atmosphere can be calculated (Ref 20). The current (i_T) produced by the target can be calculated by:

$$i_T = \frac{S_R \; \eta(\overline{\lambda}) \; \varepsilon_T \; e}{hc/\overline{\lambda}}$$

where

S_R = the area of the receiving optics

$\eta(\overline{\lambda})$ = quantum efficiency of the detector at the mean wavelength of the sensor's spectral band

h = Planck's constant

= 6.63×10^{-34} Watts second^{+2}

c = speed of light

= 3.00×10^{8} meters second^{-1}

$\overline{\lambda}$ = the mean of the sensor's spectral band

e = the charge on an electron

= 1.6×10^{-19} Coulombs

The current response (i_β) due to the atmospheric irradiance is:

$$i_\beta = \frac{S_R \; \eta(\overline{\lambda}) \; \varepsilon_B \; e}{hc/\overline{\lambda}}$$

22

Once the current response is known, the signal to noise ratio (S/N), assuming there is no source of noise other than atmospheric radiance, can be calculated by:

$$S/N = \frac{i_T/e \sqrt{tD}}{\sqrt{i_T/e + i_B/e}}$$

If the signal to noise ratio is sufficiently large, then the target can be tracked.

Submodel Descriptions

The ten major subroutines associated with the program EOBASE are SPHERE, CART, TARGET, SUNPOS, SIGHT, VISBLE, SLWIR, SIDEN, CLOUD, and TRACK. Each is briefly described in this section. Expanded descriptions of underlying models for these subroutines are found in the next chapter.

SPHERE and CART. When EOBASE is used to select the most efficient sensor system, SPHERE and CART are called to generate a sphere of operations for each sensor type. Together these subroutines calculate and store 410 points that are spread uniformly over this sphere of operations which is fixed in the geocentric equatorial coordinate system. Note that the radius of each sphere is defined by the altitude of the sensor for which it is calculated. See Figure 3 for a functional flow of SPHERE.

TARGET and SUNPOS. TARGET is used to randomly place all selected targets into their proper orbits and store the cartesian coordinates of their locations. The TARGET algorithm uses a random selection from a uniform $(0,2\pi)$ distribution for the mean anomaly, a root solution

23

```
                    ┌─────────────┐
                    │    START    │
                    └──────┬──────┘
                           │
                           ▼
                 ┌──────────────────────┐
                 │ DEFINE THETA ANGLES  │
                 └──────────┬───────────┘
                            │
     ┌──────────────────────┼──────────────────────┐
     │                      ▼                       │
     │          ┌──────────────────────┐            │
     │          │ GO TO THE FIRST (NEXT)│           │
     │          │     ANGLE THETA       │           │
     │          └──────────┬───────────┘            │
     │                     │                        │
     │   ┌─────────────────┼────────────────┐       │
     │   │                 ▼                │        │
     │   │      ┌──────────────────────┐     │       │
     │   │      │ GO TO THE FIRST (NEXT)│    │        │
     │   │      │   ANGLE PHI ON THIS   │    │        │
     │   │      │    LATITUDE THETA     │    │        │
     │   │      └──────────┬───────────┘     │       │
     │   │                 ▼                │        │
     │   │      ┌──────────────────────┐     │       │
     │   │      │     CALL CART TO      │    │        │
     │   │      │ COMPUTE THE CARTESIAN │    │        │
     │   │      │COORDINATES OF THE POINT│   │        │
     │   │      │ OF RADIUS R, AND ANGLES│   │        │
     │   │      │    THETA AND PHI      │    │        │
     │   │      └──────────┬───────────┘     │       │
     │   │                 ▼                │        │
     │   │              ◇ LAST ◇            │        │
     │   └──────── no ─◇ ANGLE PHI FOR ◇    │        │
     │               ◇ THIS THETA? ◇        │        │
     │                  ◇    ◇               │        │
     │                     │ yes            │         │
     │                     ▼                          │
     │              ◇ LAST ANGLE ◇                    │
     └───────── no ─◇   THETA?   ◇                    │
                     ◇        ◇
                        │ yes
                        ▼
                 ┌─────────────┐
                 │    STOP     │
                 └─────────────┘
```
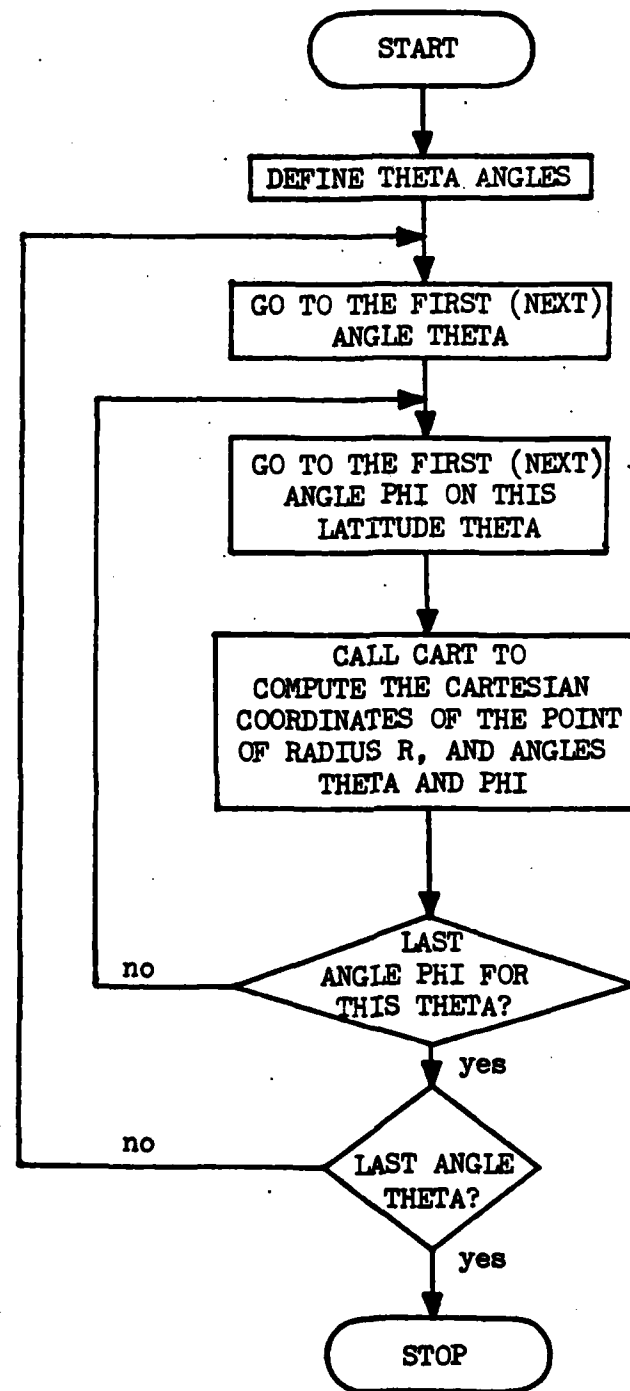
Figure 3.   Submodel SPHERE logic diagram

24

to Kepler's equation for the eccentric anomaly, and a conversion to the true anomaly. In addition, TARGET calls subroutine SUNPOS to randomly place the position of the sun with respect to the latitude and longitude that is oriented over the earth. See Figure 4 for the functional flow of TARGET.

SIGHT. The purpose of SIGHT is to determine whether or not a target can be tracked by a particular sensor from a given location. SIGHT's answer is yes or no. If the target cannot be tracked, SIGHT returns the calling program a score of 0.0. Conversely, if the target can be tracked, SIGHT returns a value of 1.0. SIGHT uses the subroutine VISBLE or the subroutine LWIR. See Figure 5 for the functional flow of SIGHT.

VISBLE. Subroutine VISBLE is used to determine if the amount of visible radiation from the sun reflected to a particular sensor is sufficient for the target to be detected. For the sake of simplicity, the algorithm used in VISBLE assumes that the target is a simple earth center oriented cylinder. See Figure 6 for the functional flow of VISBLE.

SLWIR. The purpose of subroutine SLWIR is to determine if a LWIR sensor can track a target satellite. SLWIR assumes the target is a Lambertian surface at 300 degrees Kelvin with one square meter of surface area presented to the sensor. See Figure 7 for the functional flow of LWIR.

SIDEN. Subroutine SIDEN uses the subroutines TARGET and SIGHT to generate an "average target system sighting efficiency" value for each point on each sensor type's sphere of operations. Subroutine SIDEN

25
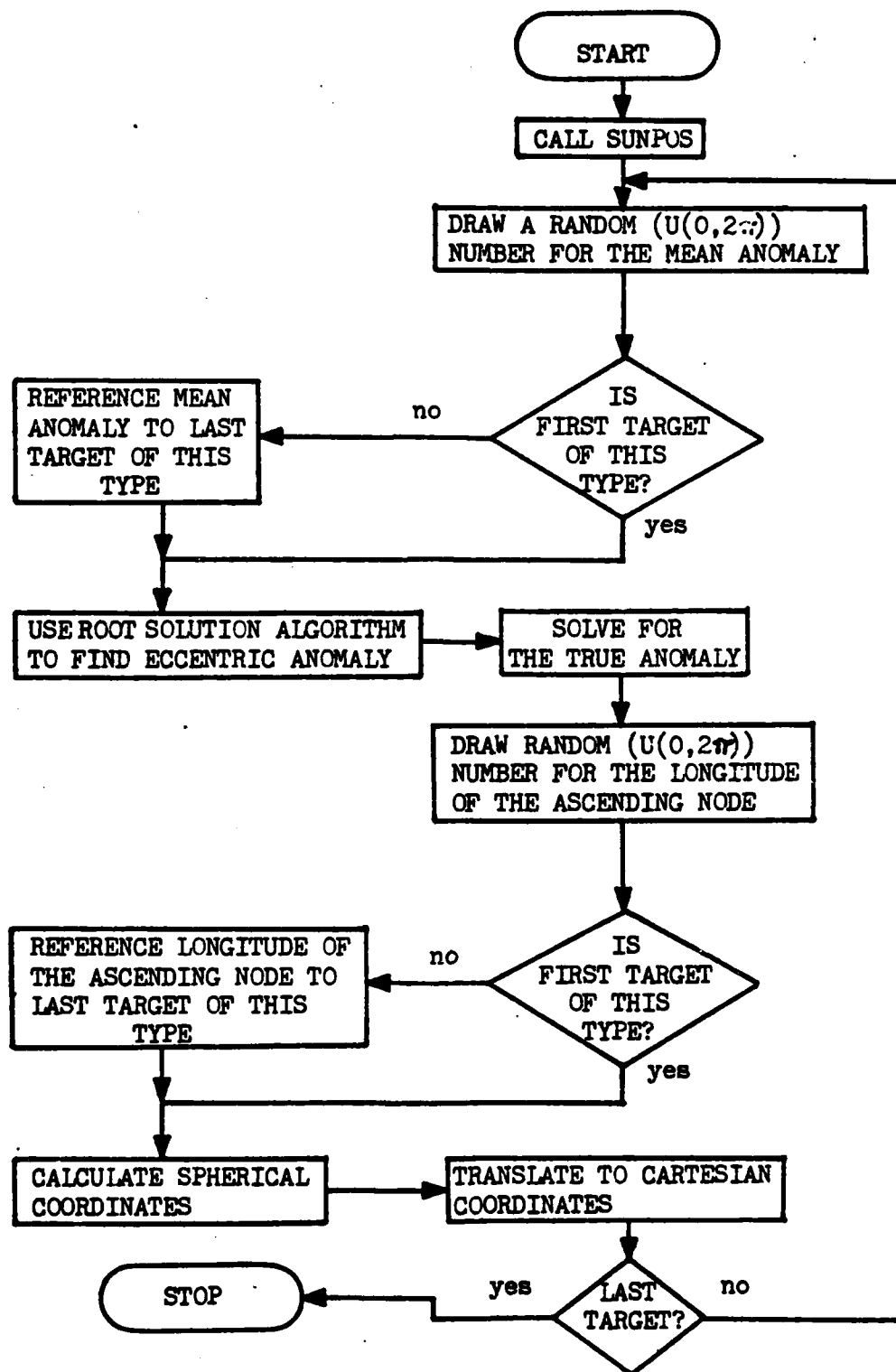
Figure 4. Submodel TARGET logic diagram.
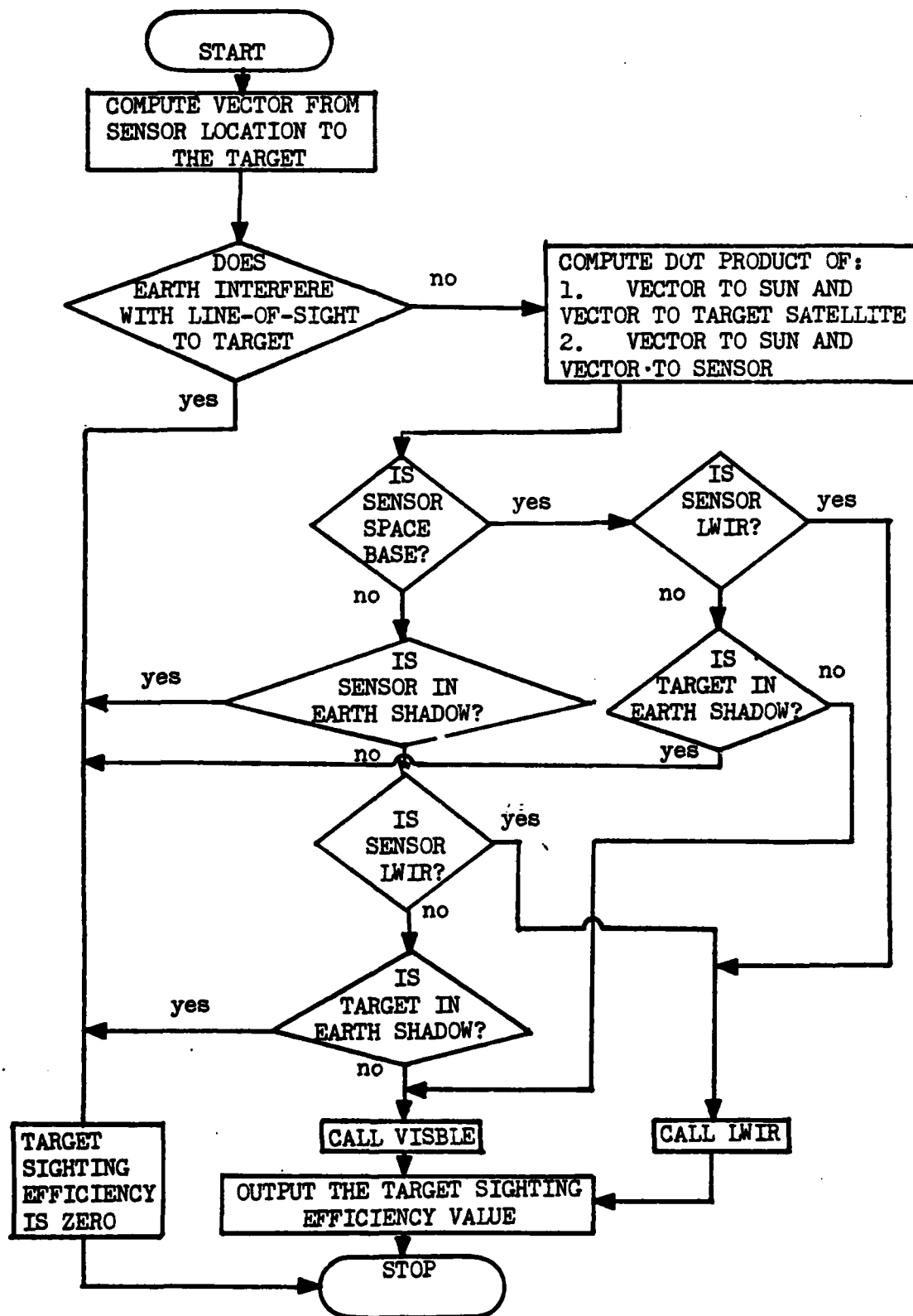
Figure 5. Submodel SIGHT logic diagram.

27
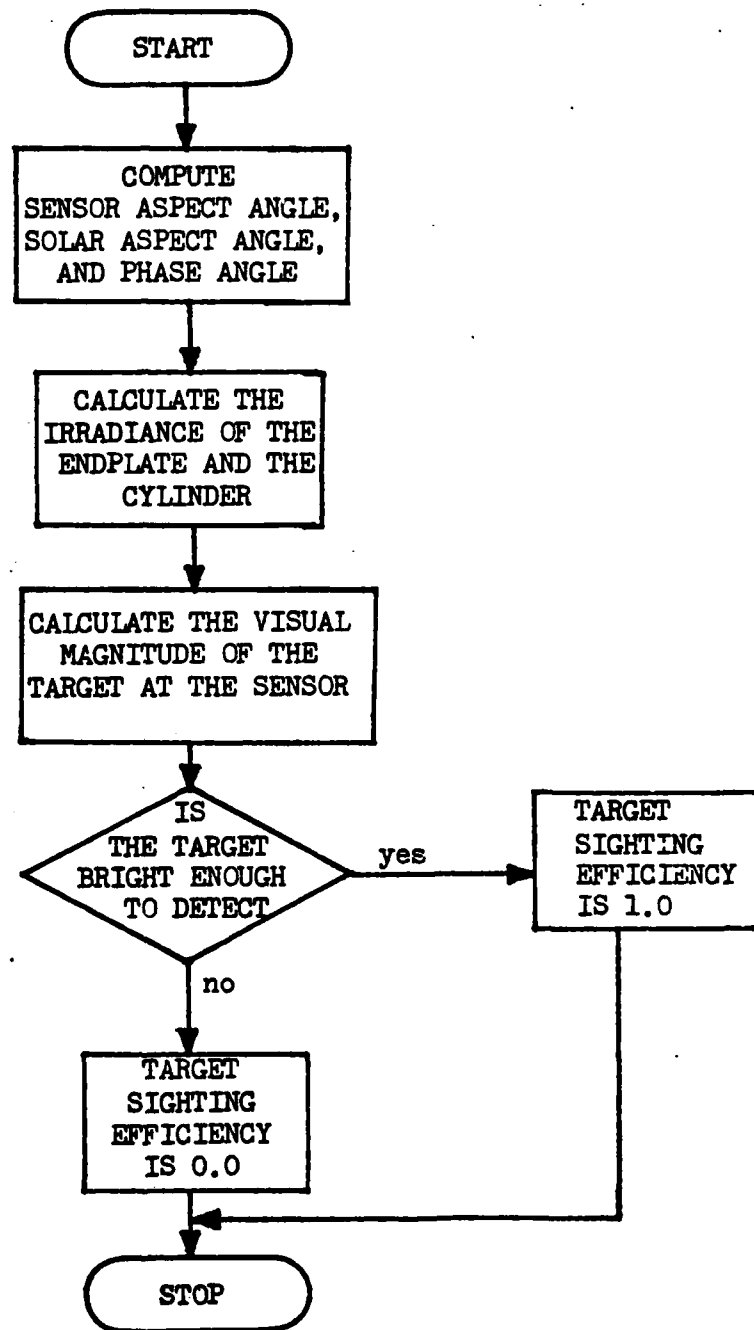
Figure 6.   Submodel VISBLE logic diagram.

28
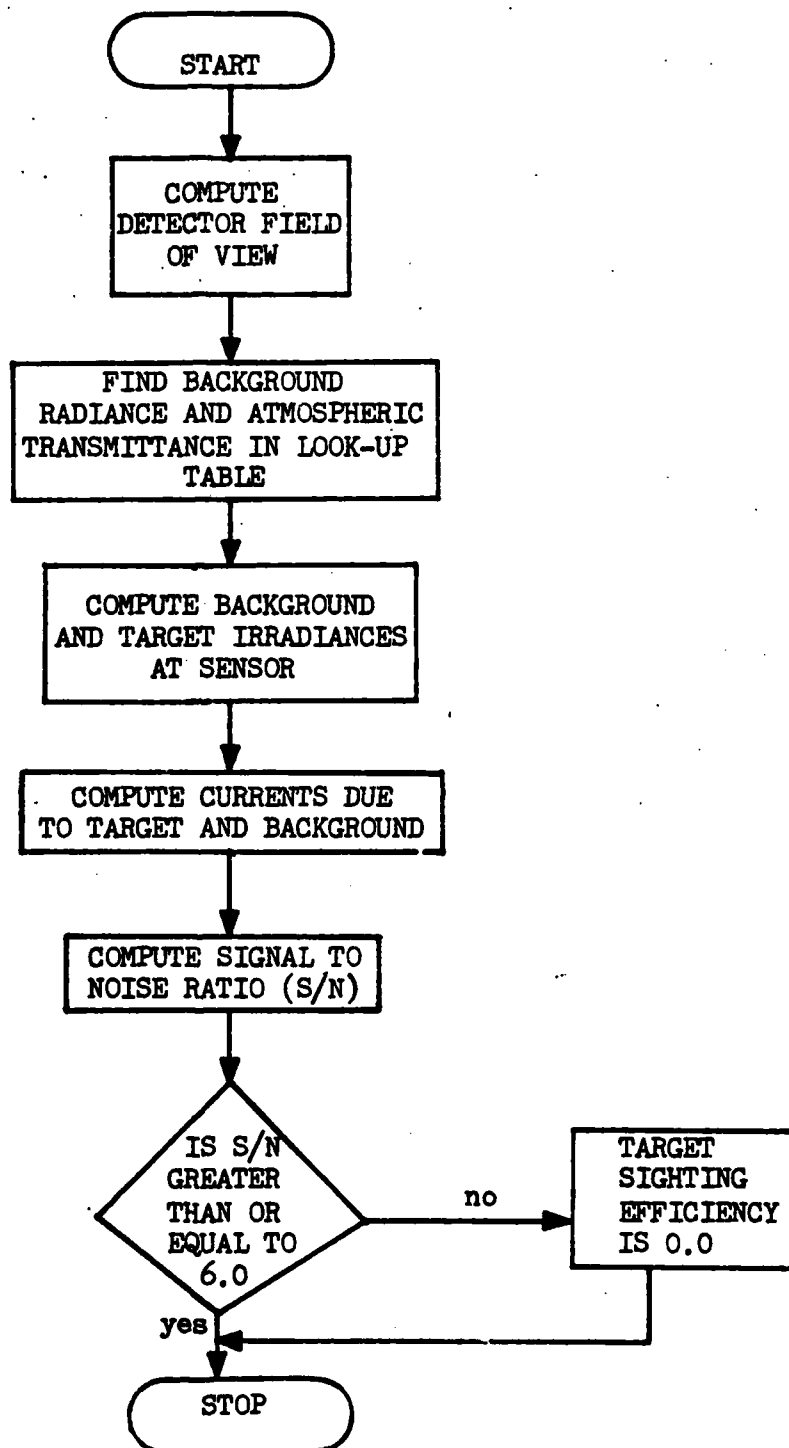
Figure 7. Submodel SLWIR logic diagram.

does this by having TARGET randomly place the targets into their orbits and then it uses SIGHT to score each point on each sphere of operations with respect to each target. See Figure 8 for the functional flow of SIDEN.

CLOUD. The purpose of subroutine CLOUD is to simulate the amount of cloud cover at ground-based sensor site locations and then determine if the sensor is still functional. CLOUD is called only when preselected ground-based sensor site locations have been entered into the program. See Figure 9 for the functional flow of CLOUD.

TRACK. Subroutine TRACK is the portion of the EOBASE model in which the simulation takes place. TRACK uses either the user supplied sensor system or the sensor system selected by EOBASE to attempt tracking the target system within the mission completion time. TRACK uses subroutines TARGET, SIGHT, and CLOUD. See Figure 10 for the functional flow of TRACK.

Main Program EOBASE

The main program, EOBASE, acts as a controlling program. EOBASE is divided into three sections, an input section, an optimization section, and a confidence section. The optimization and confidence sections of EOBASE, together with its various subroutines, provide the EOBASE with the capability to select the most efficient sensor system from the input sensor types to accomplish a given mission. In the event the user wishes to evaluate a preselected weapons system, the optimization section is bypassed and TRACK is called the number of times requested. See Figure 11 for a functional flow of EOBASE.

30

START

CALL TARGET TO PLACE THE TARGETS

GO TO FIRST (NEXT) SPHERE OF OPERATIONS

GO TO THE FIRST (NEXT) POINT ON THE CURRENT SPHERE OF OPERATIONS

GO TO THE FIRST (NEXT) TARGET SELECTED

CALL SIGHT TO GENERATE THE SIGHTING EFFICIENCY

ACCUMULATE SIGHTING EFFICIENCIES FOR EACH POINT

no — LAST TARGET ?

yes

no — LAST POINT ?

yes

no — LAST SPHERE ?

yes

no — LAST TARGET PLACEMENT ? — yes — STOP
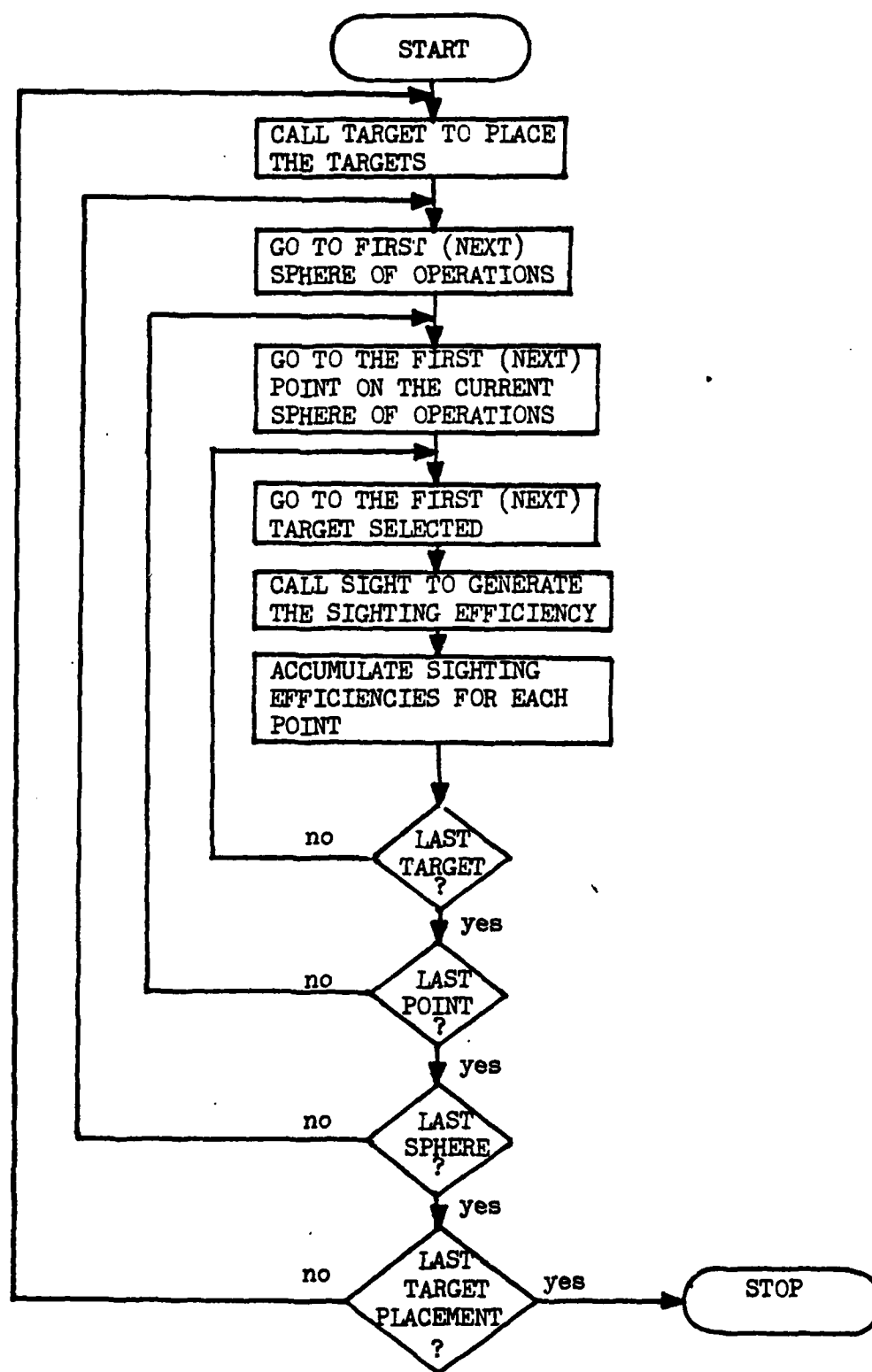
Figure 8. Submodel SIDEN logic diagram.

31
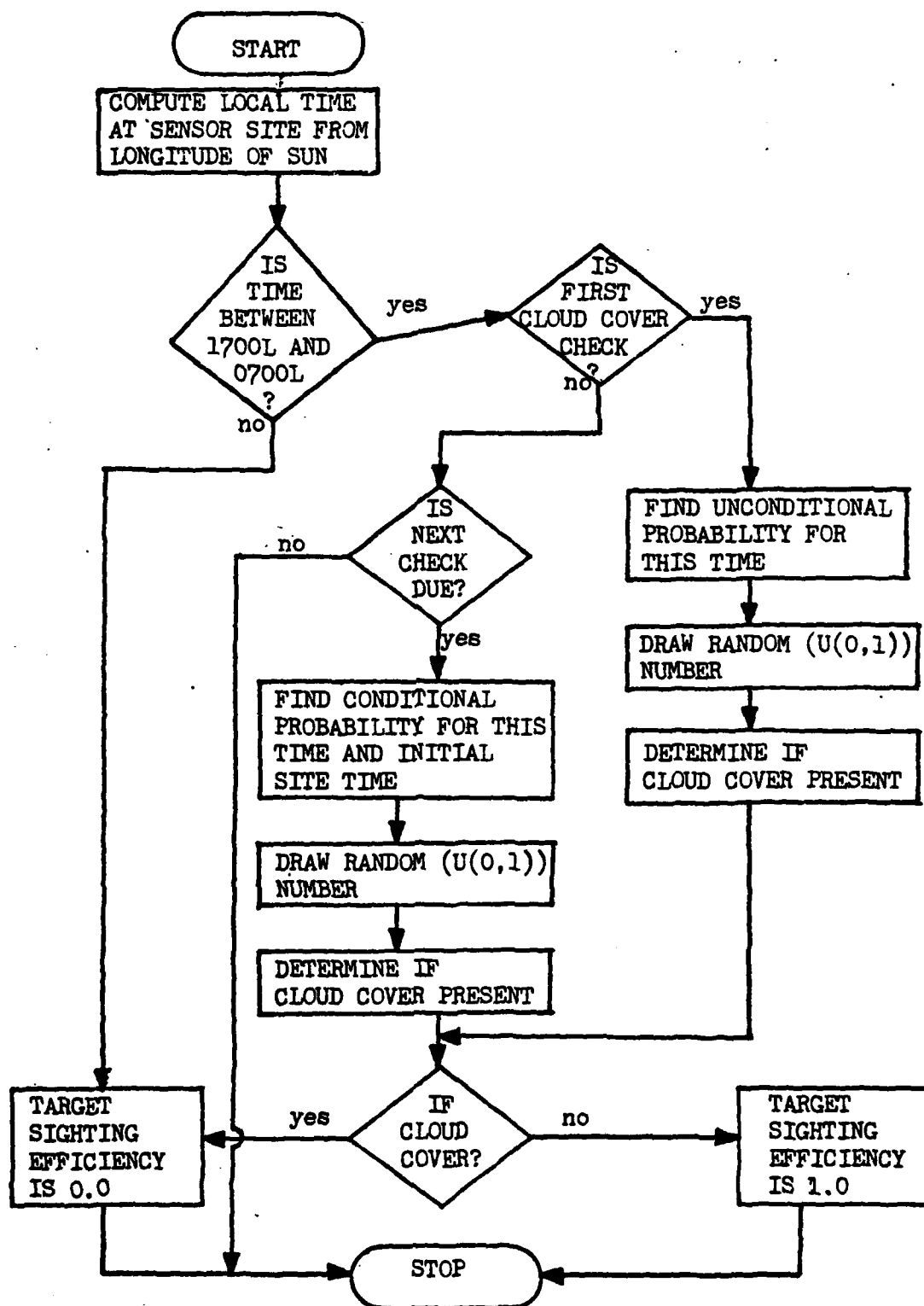
Figure 9. Submodel CLOUD logic diagram.

32
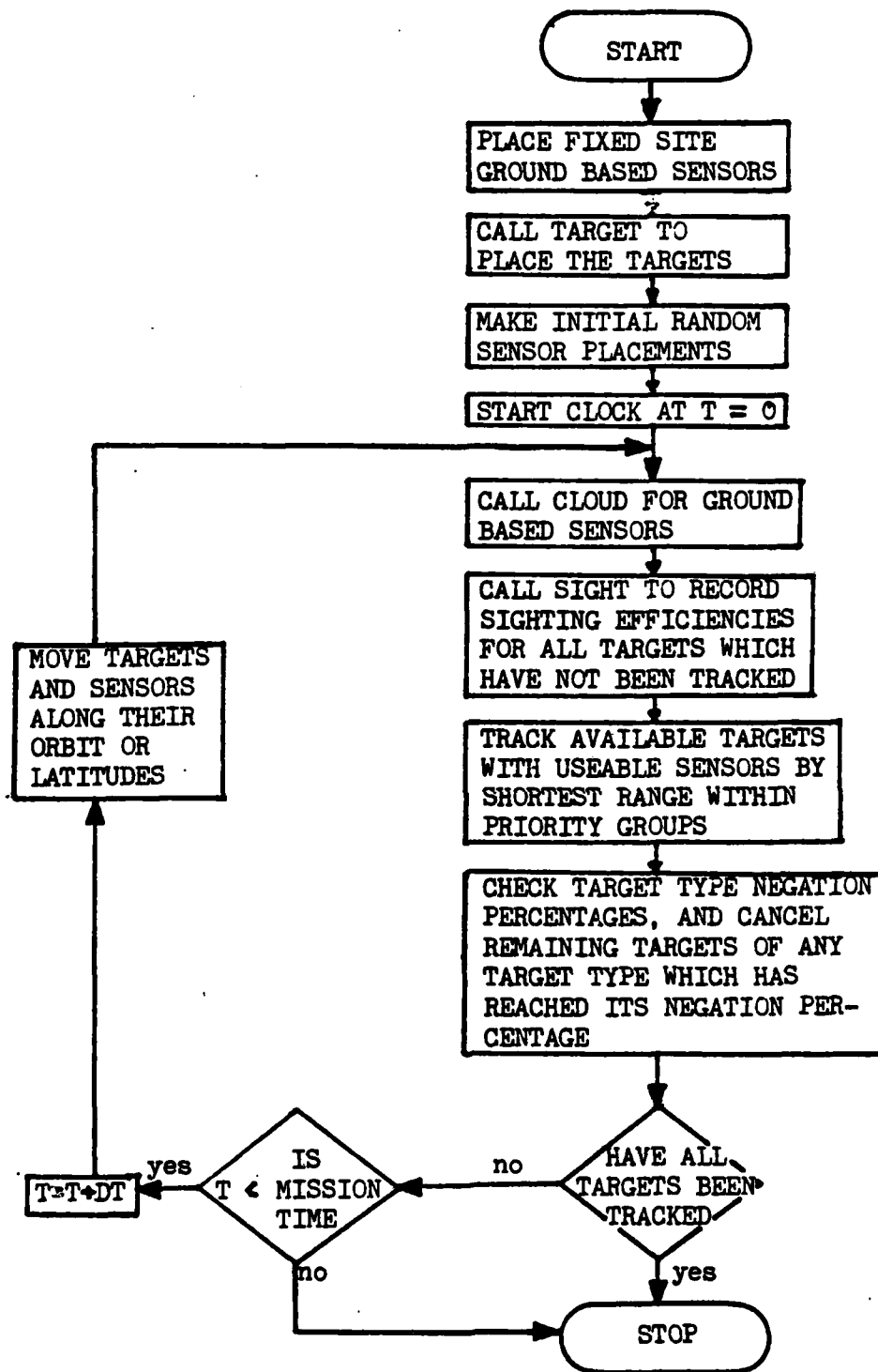
Figure 10. Submodel TRACK logic diagram.
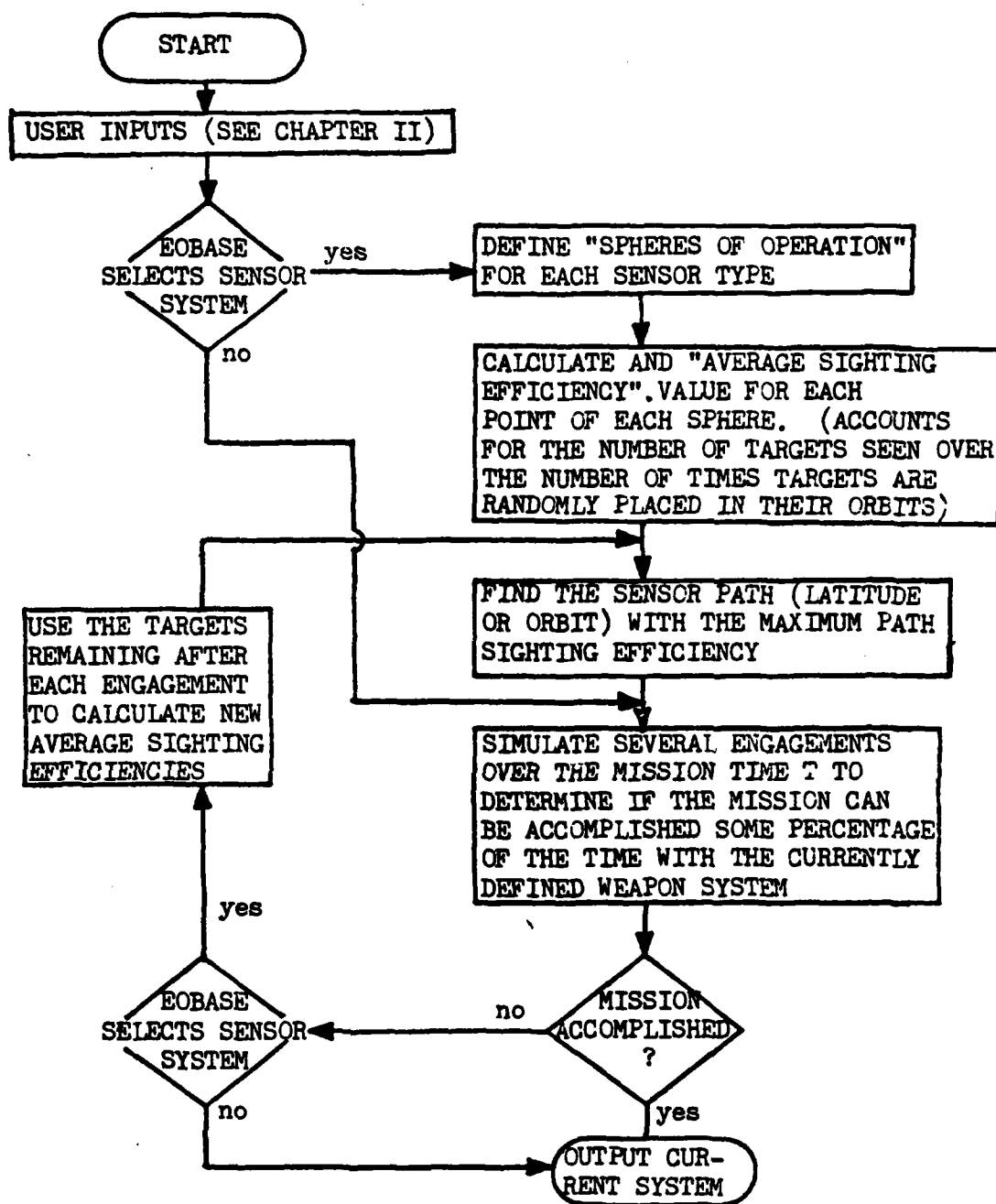
Figure 11. EOBASE function flow.

34

Input Section. This section of EOBASE reads in all user inputs
and writes them back for verification. In addition, SPHERE is called
to generate the sphere of operations for each sensor type when the
user directs EOBASE to select the most weapons system.

Optimization Section. The purpose of this section of the program
is to place the first (next) best sensor in the most efficient orbit or
latitude. The average target system sighting efficiencies, generated
by SIDEN, are used to decide the first (next) best sensor/path choice.
SIDEN is called each time a sensor is placed.

Confidence Section. The confidence section of the program runs
TRACK several times to determine if the selected sensor system can meet
mission requirements. If EOBASE is being used to select the most
efficient sensor system, the percentage of time the selected sensor
meets mission requirements is compared with some user selected
percentage. In the event that the user selected percentage is higher,
SIDEN is called, and then control is passed to the optimization section
and another sensor is added to the sensor system. Otherwise, EOBASE
writes out the final selected sensor system. If the user wishes to use
EOBASE to evaluate a preselected sensor system, the confidence section
is used to run TRACK the requested number of times.

Summary. The purpose of the EOBASE simulation program is twofold;
the program can be used to select the most efficient sensor system
which will meet mission requirements given no knowledge of the time of
the tracking sequence initiation, or the program can be used to
evaluate a preselected system. This chapter has included a functional
description of EOBASE and its submodels, and it is concluded with a

35

table summarizing these submodels, their functions, inputs, and outputs
see Table V). Chapter III provides an explanation of the concepts
employed by each of the EOBASE submodels, and it describes the efforts
which were made to validate the EOBASE program.

TABLE V

Summary of Submodel Functions

Submodel	Function	Inputs	Outputs
SPHERE	Calculate and store cartesian coordinates of points on a sphere of operations	Radius	Cartesian coordinates of a sphere of operation
TARGET	Place targets randomly into orbits	Target type selections	Cartesian coordinates of all targets
SUNPOS	Place sun above earth	Sun type selection	Unit vector to and longitude of sun
SIGHT	Determines feasibility of sighting target	Target, sun, and sensor locations, sensor type, and target type	Target sighting efficiency
VISBLE	Calculates visual magnitude of target at sensor	Sensor type, vectors to target from origin and sensor, vector to sun, and range to target	Target sighting efficiency
SLWIR	Calculates signal to noise ratio for target irradiance versus background irradiance	Sensor type, zenith angle, range to target	Target sighting efficiency
SIDEN	Establishes the target system sighting efficiency for each point on each sphere of operations	Sensor type, target type, sun type, and spheres of operation	Values of target system sighting efficiency

(continued)

36

TABLE V (continued)

Summary of Submodel Functions

Submodel	Function	Inputs	Outputs
CLOUD	Simulates effect of cloud cover on ground based sensor	Longitude of sun, longitude of sensor, sky cover probabilities	Target sighting efficiency
OPTIMIZE	Select most efficient sensor orbit or latitude to place first (next) sensor	Average target system sighting efficiencies	Sensor system locational parameters
TRACK	Engage targets in accordance with mission data	Sensor system, target system, mission data	Number of targets tracked and target system tracking time

III   Model Development

The previous chapter provided a functional description of EOBASE and its submodels. This chapter contains a description of the concepts employed by each of the various submodels described in Chapter II. In addition, the efforts made to validate EOBASE are presented.

Sphere of Operations (Subroutine SPHERE)

A "sphere of operations" is a stationary sphere in the celestial reference system, and it is used to represent all of the possible basing locations for a particular sensor type (see Refs 17 and 18 for a more complete explanation).

Placement of Points. EOBASE uses 410 points to define a sphere of operations. This number is the same as chosen for HELBASE (Ref 18:Ch 2, 29), and it was chosen as a tradeoff between accuracy run time and computer core memory requirements. The 410 points are distributed among 19 latitudes starting with the equator and heading north and south in 10 degree increments. The number of points on each latitude is the number of points required to achieve the closest approximation to a 10 degree arc spacing (see Table VI). Subroutine SPHERE calculates the cartesian coordinates for each of the 410 points for each sphere of operations.

Ground and Air Basing Modes. The sphere of operations for ground based sensors is the mean surface of the earth. For air-based sensors,

38

TABLE VI

Number of Points on Each 10 Degrees of Latitude

True Latitude (degrees)	Number of Points
0	36
10	35
20	34
30	31
40	27
50	23
60	18
70	12
80	6
90	1

Note: The southern hemisphere is a mirror
        image of the northern hemisphere.

the sphere of operations is 21 kilometers (70,000 feet) above the mean

surface of the earth. The choice of this altitude is due to the

existence of a minimum wind velocity at this altitude (Refs 11 and 23).

A typical example of this minimum is shown in Figure 12. As noted by

Petrone and Wessel (Ref 11), although a considerable penalty in weight

and complexity is exacted at this altitude, the required power is much

less (except of course at altitudes near sea level). As a first

approximation, drag (power consumption) and lift (power available) are

proportional to density while power consumption increases as the cube

of the velocity; thus a minimum in the velocity altitude curve

represents an optimal point for operations.

The possible alternatives for positioning a sensor in these modes

are limited to the set of latitudes from 60 degrees north through

60 degrees south spaced in 10 degree intervals. The position of both

ground-and air-based sensors is considered fixed with respect to the
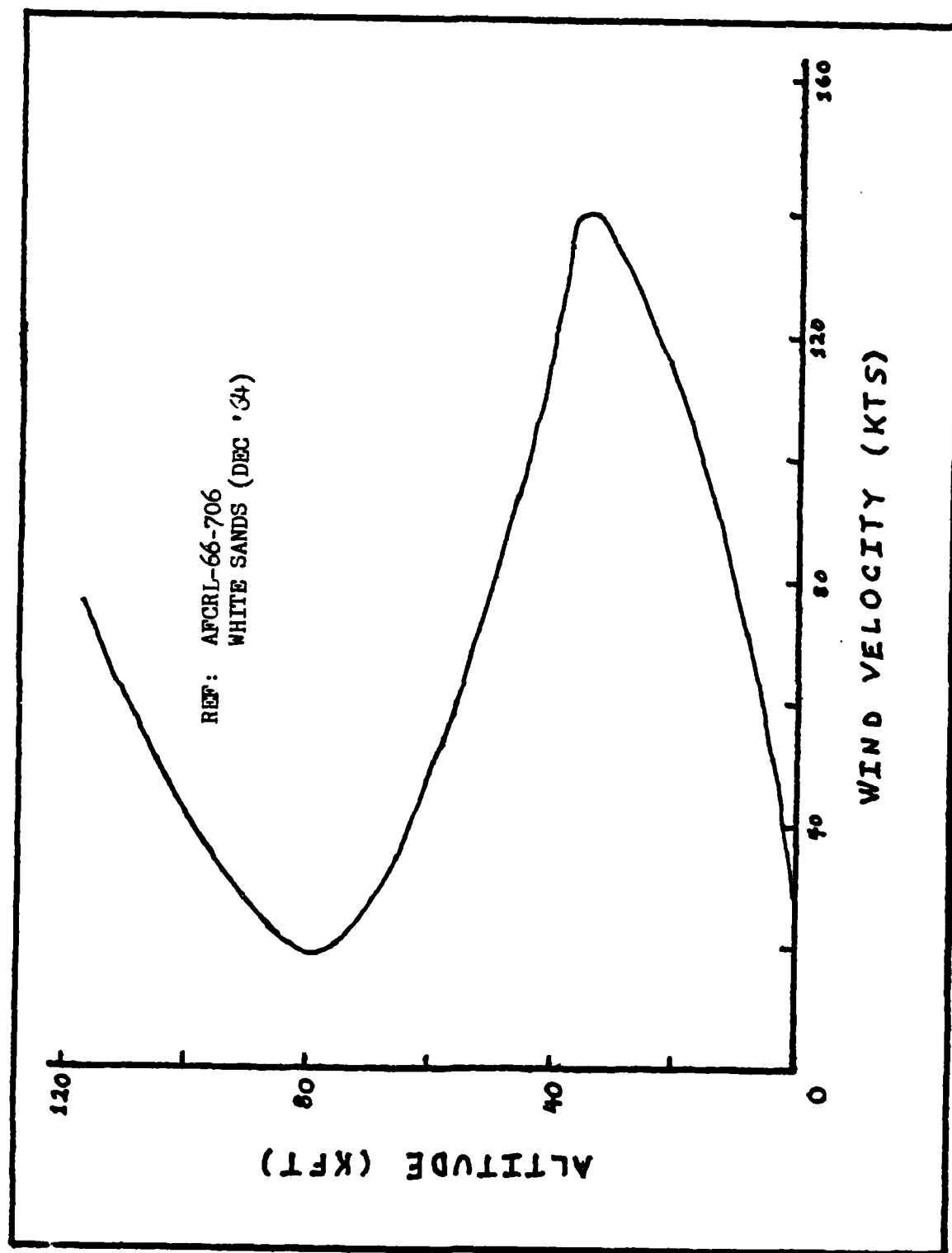
Figure 12. Typical wind velocity profile.

earth, however, since the earth rotates over time, selection of a particular longitude is not necessary. So, the sighting efficiency for a latitude is approximated using the average sighting efficiency of the set of evenly spaced points at that latitude.

Space-Basing Mode. The space-basing mode is also available in EOBASE. The sphere of operations for a sensor type in the space-based mode is defined by a sphere at some given radius from the earth's center. Since orbits precess at different rates based upon their altitude, inclination, and eccentricity, the longitude of the ascending mode for a sensor is randomly chosen by EOBASE. The inclination of an orbit is the only parameter which must be selected. The inclinations considered are 0, 15, 25, ..., 85, and 90 degrees. Each inclination alternative is defined by the points which lie over a latitude which is less in degrees from the equator than the inclination of the orbit. These points are used to model the band swept out by an orbit as it precesses around the earth in time. The average of the sighting efficiencies for all the points which fall within the band is used to describe the sighting of the orbit.

TARGET and SUNPOS

Subroutine SUNPOS, when called by TARGET, uses the user input SUNTYP to determine how to place the sun over the earth. SUNTYP can have the values 1, 2, 3, or 4. With the values 1, 2, or 3, the latitude over which the sun is oriented is fixed. The value 1 causes the sun to be placed over the equator, 2 at 23 degrees north, and 3 at 23 degrees south. The value of 4 causes the sun to be randomly placed between 23 degrees north and 23 degrees south. The procedure for

41

randomly placing the sun assumes a circular orbit for the earth around
the sun so that the number of days since the last vernal equinox can
be randomly chosen from a uniform (0,365.25) distribution. Then the
angle between the earth at its randomly chosen position and its
position at the vernal equinox (relative to the sun) can be calculated
by:

$$\theta = \frac{2\pi \text{ rad.}}{365 \text{ days/year}} \text{ number of days since last vernal equinox}$$

From θ the declination angle (δ) to the sun, that is the angle
between the earth's equatorial plane and the vector to the sun, can be
calculated as shown below (Ref 24).

$$\delta = \sin^{-1} (\sin \varepsilon \sin \theta)$$

where

   ε = the angle between the earth's equatorial plane and the
   ecliptic plant

   = 23 degrees

If a spherical earth is assumed, this last calculation provides the
latitude over which the sun resides since latitude and declination
angle then become equivalent concepts. In all four cases or sun
types, the longitude is randomly selected from a uniform (0,2π)

42

distribution. Once the latitude and longitude are chosen, SUNPOS then calculates a unit vector to the sun.

Subroutine TARGET itself uses the orbital parameters of the selected target satellites to randomly place them into their orbits. Two orbital parameters are randomly selected, mean anomaly (M) and the longitude of the ascending mode (Ω). Both are randomly drawn from a uniform $(0, 2\pi)$ distribution. In order to position the satellite, the mean anomaly is converted to the true anomaly using the "mean anomaly to true anomaly technique" (Ref 25:185). M is related to the eccentric anomaly by:

$$M = E - e \sin E$$

where

e = the orbital eccentricity

A numerical technique is used to find E. Then E is used to calculate the true anomaly, V, by:

$$V = \cos^{-1} \left[\frac{e - \cos E}{e \cos E - 1} \right]$$

Note that the numerical solution procedure is not necessary where e = 0, since in this case M = E = V.

SIGHT

Subroutine SIGHT is used to determine the feasibility of tracking a target at one point by a sensor at another given location. Several

43

checks are made by Subroutine SIGHT. The first check is for line-of-sight interference with the earth. Next, in the case of ground and air based sensors, a check is made to determine if the sensor is on the dark side of the earth. Then, in the case of sensors employing visible light, a check is made to determine if the target is in the earth's shadow. Finally, Subroutines VISBLE (for visible light detecting sensors) and SLWIR (for LWIR detecting sensors) are used to determine if the quantity of light from the target reaching the sensor is sufficient for detection of the target to occur. If any of these checks are violated, the subroutine returns a sighting efficiency value of 0.0 for negative acquisition. However, if all the checks are passed, a value of 1.0 is returned which indicates that tracking of the target is feasible.

All of these checks are made with vector algebra using the appropriate vectors. For example, whether or not ground and air-based sensors are on the earth's dark side is determined using the inner dot product of the vector to the sensor and the unit vector to the sun. A negative value indicates that the sensor is in the earth's shadow.

VISBLE and SLWIR

The basic principles employed in VISBLE and SLWIR have been previously explained as part of sensor operations in Chapter II.

In the case of the visible light detecting sensors, Subroutine VISBLE is used to calculate the required angles: α, β, and ϕ. These angles together with the target's range from the sensor, and the target's plate and cylinder areas (these areas are stored with the target's orbital parameters) are used by VISBLE to calculate the visual

44

magnitude of the target at the sensor. The value must be less than the maximum required by the sensor for detection to occur.

Subroutine SLWIR is used in the case of the air-based LWIR sensor. SLWIR is supplied with the angular resolution of the telescope, which it converts to the detector field of view, and the detector dwell time as user inputs under sensor type. Subroutine SIGHT provides the angle from the zenith and the range to the target. Also, SLWIR uses two permanently stored arrays which contain the values for the atmospheric radiance and transmittance for a standard U.S. atmosphere (Ref 26) looking into space from 21 kilometers at zenith angles from 0 to 80 degrees at intervals of 10 degrees. In addition, SLWIR contains the assumptions that the target is a Lambertian surface 1.0 meter in diameter, at 300 degrees Kelvin, with a radiance of $(44/\pi)$ Watts meter^{-2} steradran^{-1} (over the spectral range from 10.5 micrometers to 12 micrometers); that the receiving optics are 1.0 meter in diameter; that the detector efficiency is .25; and the sensor has a bandpass 10.5 micrometers to 12 micrometers. With these assumptions and inputs, SLWIR calculates a signal to noise ratio. If the ratio is greater than or equal to 6.0, the sensor is considered capable of detecting the target satellite.

SIDEN

Subroutine SIDEN is used to calculate an average sighting efficiency for each point on the sphere of operations for each sensor type. These sighting efficiencies are used by the OPTIMIZE to generate path sighting efficiencies for all possible paths for each sensor type.

For one point looking at a target, Subroutine SIGHT returns with S, the sighting efficiency, with a value of 0.0, target not sighted, or

45

1.0, target sighted. With n targets, the target system sighting
efficiency is calculated by:

$$\overline{S} = \sum_{k=1}^{n} S_k$$

where

S_k = the sighting efficiency of the k_{th} target

Since the targets and the sun are randomly placed, the system sighting
concept can be extended for m iterations to achieve greater accuracy by
calculating an average target system sighting efficiency (EFF). EFF is
calculated by:

$$EFF = \sum_{j=1}^{m} \sum_{k=1}^{n} S_{jk}$$

where

S_{jk} = the sighting efficiency of the k_{th} target at the
j_{th} iteration

The input variable JCOUNT is equal to j and determines the number of
iterations used to calculate EFF.

CLOUD

Subroutine CLOUD is called by Subroutine TRACK to simulate the
interference of cloud cover with ground-based sensor operations. The

46

major assumptions demonstrated in this submodel are: (1) a ground based sensor is relatively ineffectual at greater than 3/8 sky cover and effective at less than or equal to 3/8 sky cover, (2) the percentage of total sky cover tends to be either extremely low or extremely high, and (3) the amount of total sky cover does not tend to change radically in less than 3 hour intervals. The basis for the first assumption is the Air Defense Comand's (ADCOM) criteria for site selection for the GEODSS sites (Ref 27). ADCOM has used the decimal fraction of less than or equal to 3/10 sky cover over the tracking period (1800 hours to 0600 hours) as one measure of effectiveness for the candidate GEODSS sites. Previous experience with the Baker-Nunn camera system has found that the average number of tracks submitted is approximately equal to the square of the probability of less than or equal to 3/10 sky cover times the number of scheduled tracks. The 3/8 sky cover figure was used in this study for two reasons: (1) sky cover is usually reported in eighths and (2) GEODSS is expected to do 30 to 40 percent better than the Baker-Nunn system (Ref 27). The second assumption is based upon existing data and observations. For example, Lund and Shanklin (Ref 28) report that, of over 12,000 observations, 57 percent were either 0/10 sky cover or 10/10 sky cover. The third assumption is also based upon observation. Lund and Shanklin (Ref 29) indicate that initial conditions for a line of sight will on the average persist, whether cloud free or cloudy, for a greater than 3 hour period more than 50 percent of the time

CLOUD operates in the following sequence. First, CLOUD determines the local site time relative to the longitude over which the sun

47

resides. Then, if the time falls between 1700 hours and 0700 hours local, CLOUD checks the appropriate (see Table IV in Chapter II) unconditional probability for that time relative to a random number selected from a uniform (0,1.0) distribution. Thereafter, based upon the results of the comparison, the initial sky cover condition is established and the appropriate conditional probability is checked at 3-hour intervals.

OPTIMIZE

OPTIMIZE, a section of the main program EOBASE, is used when the user wishes to have EOBASE identify the most efficient sensor system. OPTIMIZE uses the output from SIDEN to search all the allowable paths for the path with the highest "path sighting efficiency." For ground and air-based sensors, a "path sighting efficiency" at each latitude from 60 degrees north to 60 degrees south at 10 degree intervals is calculated. For space-based sensors, there are ten orbital "bands" which are defined by the inclinations of the orbits. As noted in the first section of this chapter, "Spheres of Operation," the coordinates supplied by Subroutine SPHERE are used to model these orbital and latitudinal paths (see Refs 17 and 18 for further details).

TRACK

Subroutine TRACK is used by the confidence section of EOBASE to simulate, at some random starting time, a tracking engagement between the selected sensor and target systems over the mission time. TRACK has dual purposes. If the sensor system is supplied by the user, TRACK merely simulates the number of tracking engagements indicated. If,

48

however, the sensor system is supplied by EOBASE, then the confidence section of EOBASE uses TRACK to check the adequacy of the sensor system in terms of meeting the mission requirements. If the sensor system is found to be inadequate, then OPTIMIZE is used to select another sensor for the sensor system.

Sensor Placement. Several methods are used to place sensors. These methods differ according to the basing mode of the sensors and according to whether or not the sensor system is user or EOBASE selected. In the case of user selected ground-based sensors, the sensor's coordinates are already specified, latitude, longitude, and altitude. So, TRACK merely converts these coordinates to cartesian coordinates. In the case of air- and space-based sensors, only the latitude or the inclination and the altitude respectively are supplied by the user. Therefore, TRACK must calculate the remaining positioning coordinates. Air-based sensors are placed so that the sensors occupy equally spaced longitudes around the globe. The basing longitude of the first sensor to be placed is randomly chosen, and all the other air-based sensors are located with respect to it. The sensors on the latitude on which the most sensors are located are placed first to prevent a large number of sensors from being clumped together on the same latitude on the same side of the globe. Then the latitude with the next largest number of sensors is considered, and so forth. Space-based sensors are arranged by giving sensors which share the same inclination equally spaced values for the mean anomaly and the same value for the longitude of the ascending mode. EOBASE selected ground-based sensors are placed in the same way as air-based sensors.

It should be emphasized that TRACK does not consider geographical features as part of the sensor placement process. Sensors, therefore, may be placed at unrealistic locations such as broad ocean areas or even the Soviet land mass. Nonetheless, the system configuration selected by EOBASE is a good indication of what the relative positions of the sensors should be.

Target and Sensor Movement at Each Δt. All sensors and targets are assigned initial locations at the beginning of each tracking sequence. For targets and space sensors, the initial position in orbit is determined by a random selection of the mean anomaly and the longitude of the ascending mode. At each time increment (Δt), the mean anomaly advances (ΔM). This effect is given by:

$$\Delta M = (\mu/a^3)^{1/2} \; (\Delta t)$$

where

$\mu = 3.986 \times 10^5 \; km^3/sec^2$

a = semimajor axis of the orbit

The new mean anomaly is then calculated and converted to the true anomaly, and from this, the new position is found.

The movement of ground and air-based sensors is due to the rotation of the earth with respect to the fixed geocentric coordinate frame. The effect of the earth's rotation can be determined by adding the rotation of the earth to the previous location; thus moving the sensor to a new longitude L. The new L is calculated by:

$$L = Lo + 2\pi \; (\Delta t/1440)$$

where

Lo = the previous longitude

50

EOBASE Validation

The "Towards Validation" methodology proposed by Haley and Ghelber (Ref 30) was used as a guideline for the EOBASE validation process. The process is divided into four parts: (1) conceptualization, (2) verification, (3) credibility, and (4) confidence.

Conceptualization. The purpose of this step is to determine if the early stages of model development are reasonable and valid. This includes a statement of the model's purpose, degree of accuracy, assumptions, limitations, and a structural framework. These items are contained in Chapters I and II and in this chapter and have been coordinated with experts in the areas of operations research, physics, and astrodynamics.

Verification. There are four parts to the verification process: (1) structural walk-through, (2) verification of technical processes, (3) simulation of predictable states, and (4) testing of stochastic events. The structured walk-through was accomplished for all subroutines as well as the overall EOBASE simulation. See Chapter II for descriptions of the event-path logic flow diagrams for all subroutines. The technical processes associated with EOBASE are discussed in detail in this chapter. Proper coding of these processes was checked by comparing subroutine outputs with hand calculations. In some cases the set of predictable states was chosen based upon extremes of what could occur in the real world. For all experiments, a basic scenario was chosen and the parameters were identical to those in Table VII unless otherwise specified. Table VIII provides the experiments (variations from Table VII) and Table IX provides a

51

TABLE VII

Basic Scenario

Initialization

SEED	421.	—
JCOUNT	40	—
NOWT	1	—
ICOUNT	40	—
DT	5.	minutes
P	.899	
INPUT	3	
INPUT2	0	
SUNTYP	1	

Sensor

Mode	1.	
Type	1.	
Cutoff/detector field of view	16.	visual magnitudes
Altitude	0.	kilometers
Cycle time	120	seconds
Dwell time	0.	seconds

Target Selection and Mission Data

Target type	4	
Negation percentage	100	
Negation time	1440	minutes
Tracking priority	1	

Ground Site Data*

Latitude	1.5708	radians
Longitude	0.	radians
Altitude	0.	kilometers
Sensor type	1.0	—
Sky cover probabilities	.5#	

---

* Three sites are entered separated by $(2\pi/3)$ radians of
longitude.

All elements of the sky cover probabilities array are set
equal to .5.

TABLE VIII

Experiment Descriptions

---

1. Three sensors: on the equator, 120 degrees apart
    Four sensors: on the equator, 90 degrees apart

2. Make one run with Target Type 4 only
    Make one run with Target Types 3 and 4

3. Three sensors: sensitivity cutoff equal to 13.5 visual magnitudes
    Three sensors: sensitivity cutoff equal to 16 visual magnitudes

4. Make one run with sky cover probabilities all equal to .5
    Make one run with sky cover probabilities all equal to 1.0

5. Three sensors: equally spaced around the globe at 30°N, 0°,
                    and 30°S, SUNTYP = 2
    Three sensors: equally spaced around the globe at 30°N, 0°,
                    and 30°S, SUNTYP = 3

TABLE IX

Experiment Results

Experiment	Predicted results	Actual results
1	Target system negation times shorter with four sensors	*
2	Target system negation times longer with second target type	*
3	Sensor system with lower sensitivity cut-off has longer target system negation times	*
4	Run with sky cover probabilities equal to 1.0 has shorter target system negation times	*
5	Sensors in summer hemisphere track fewer targets than sensor in winter hemisphere	*

---

* Actual results matched predictions.

53

comparison of expected results to the actual results. Testing of
stochastic events was unwarranted since all random numbers were
selected from a uniform distribution using Fortran IV's random number
generator.

Credibility. The third phase, credibility, deals with intuitive
(face validation) and statistical (sensitivity analysis) appeal of
EOBASE. Face validation of EOBASE was accomplished by consultation
with experts in operations research and physics concerning the physical
processes modeled and the structure of the model. Sensitivity analysis
was performed on two variables to determine their effect on accuracy
and processing time. JCOUNT was varied to determine how large it has
to be to get consistent path selections from EOBASE for an air-based
visible light detecting sensor. The same inputs described in Table VII
were used except INPUT was set equal to zero, Target Types 2 and 3 were
selected, and the sensor location and sky cover probability inputs
were deleted. A STOP was inserted into the program so that only the
first sensor path choice was output. Ten trials each of JCOUNT were
made at values of 5, 10, 20, 40, and 80. The results indicate that
JCOUNT must be at least 20 to obtain consistent path selections.
Target Type 2 appears to have the most influence upon path selection in
this case and causes the most northern latitudes to be favored. The
simulation time step Δt was also subjected to sensitivity analysis.
The same inputs as shown in Table VII were used except Target Types 2
and 3 were selected and ICOUNT was set equal to 10. As shown in
TABLE X, Δt was varied from 5 through 80. The results confirmed that
the number of successful missions increases as Δt decreases until Δt

54

equals 10 minutes. Then there is essentially no difference in the

average target system tracking time using 5 minutes versus using

10 minutes for Δt.

Confidence. Further confidence in the ability of the EOBASE model

was built by examining the cost/benefit of additional information and

TABLE X

Δt Experiment Results

Δt	Number of successful missions*
5	9
10	9
20	8
40	7
80	6

* Out of 10 trials.

by proper documentation of the model. Analysis of the sensitivity of

EOBASE to JCOUNT and Δt indicated the cost of further information.

Each iteration of JCOUNT with one sensor and six targets requires

0.3 seconds of execution time. Each time increment in TRACK with three

sensors and six targets averages 0.03 seconds of execution time.

The documentation of EOBASE is fairly thorough. A "documentation

list" described by Shannon (Ref 31, 262) requires the following:

Flow diagrams of each module and the overall model

--Chapter II

Description of inputs necessary for executing the program

--Chapter II, Appendix A, and Appendix B

55

Definitions of the program variables not used as inputs

--Appendix B

Verbal description of the purpose and function of all
modules

--Chapter II and Chapter III

Input deck set up to run

--Provided separately

Listing of program

--Appendix B

The validation results indicate EOBASE is performing as described.
The conceptual validity of the underlying physical processes and
techniques described in this chapter and Chapter II has been
coordinated with experts in physics, operations research, and
astrodynamics. Chapter IV will present analysis results comparing
the ability of ground- and air-based sensors.

IV   Sensor System Basing Mode Analysis

The purpose of this analysis is to compare the Ground-based
Electro-Optical Deep Space Surveillance (GEODSS) system with a
hypothetical system of air-based sensors. The GEODSS system is a
military project, built for the Air Force to replace the quartet of
Baker-Nunn photographic telescopes (Refs 32 and 33). The first GEODSS
station began operations in May of this year at White Sands Missile
Range southeast of Socorro, New Mexico, and three other installations
are expected to take shape during the next two years on Mount
Haleakala, Hawaii; at Taeger, Korea; and at the naval base on Diego
Garcia in the Indian Ocean. A fifth site is planned for either
Ascension Island or the Iberian Peninsula.

Each of the GEODSS sites houses three tracking instruments. Two
of the three have 1-meter apertures and a 2.1-degree field of view.
Three telescopes can detect objects as faint as magnitude 18.5,
however, in normal operation, the cutoff is 16.0. The third telescope
has a 0.4-meter aperture, a 6.0-degree field of view, and its
magnitude cutoff is 14.5. The wider field of view and faster slow
rate of the small instrument make it better suited to the study of
lower altitude, brighter satellites.

The principle advantage of the GEODSS system is that the data
analysis is rapid. The time required per track is about one minute.

57

Unlike the Baker-Nunn cameras which use photographic film, a GEODSS sensor uses a SIT vidicon imaging tube, an advanced television camera, so that data processing can be computer assisted. Thus the time consuming process of photographic development required for the Baker-Nunn camera is avoided.

The characteristics of the hypothetical air-based sensor are less easily defined. But, it is obvious that it should be like a GEODSS sensor in that it would use a vidicon tube and computer assisted data processing. Unfortunately it is also apparent that the sensor will have to weigh much less and that both this lower weight and the sensor' mode of basing would contribute to less pointing stability in the tele-scope. The reduced pointing stability would reduce the image stability in the focal plane; hence, the sensitivity of the telescope could be reduced. Fortunately, high pointing accuracy is possible with an air-based telescope. The 36-inch aperture telescope which NASA has on board a C-141 can maintain a line of sight stability of 2 arc seconds root mean square while in flight for at least 30 minutes (Ref 34). So, it is possible that the pointing stability problem can be solved.

Also, the air-based telescope has several relevant advantages. The air-based telescope receives a satellite's image with much less loss in intensity due to atmospheric absorbency. This is critical at high line of sight angles to the zenith. The LOWTRAN program was used to estimate this loss using the program's model for a standard rural atmosphere (Ref 27). The transmittance to the air-based sensor at 23 kilometer above sea level was found to be virtually 100 percent at the zenith and 38.8 percent at 90 degrees to the zenith. However, the

transmittance to the ground-based sensor was much less, only 44.6 percent at the zenith, and the transmittance dropped off as the zenith angle increased. At 60 degrees to the zenith the transmittance begins to drop off rapidly, and at 80 degrees, a sensor with a magnitude 16.0 cutoff receives too little light from a target presenting 1.0 square meters of surface area to detect it even when haze conditions are favorable. The other advantage of the air-based sensor is that the image which it receives does not suffer significantly from the atmospheric effect "seeing," which is caused by small fluctuations in the index of refraction of the atmosphere (Ref 19:26). Seeing causes a blurring of the image and thus reduces the sensitivity of the telescope.

Since these advantages may just about make up for the pointing stability problem, the sensitivity of the hypothetical air-based telescope will be treated here as equal to that of the ground-based telescope.

Methodology

The analysis was conducted in two stages. First the ability of the GEODSS system to detect the target system was characterized using the EOBASE program and then EOBASE was used to choose an air-based sensor system and assess its ability to detect the target system relative to the GEODSS system.

The data required to characterize the GEODSS system came from several sources. The literature was consulted (Refs 32 and 33) to get estimates of the sensitivity of the sensor and the rate at which data from it could be processed. The coordinates of the GEODSS system used

in this study are from a list provided by DODR, NORAD Headquarters, Colorado Springs, Colorado. Table XI provides a list of the five sites selected for this study. While this list does not necessarily represent the final configuration of the GEODDS system, it is a viable one. The sky cover probabilities for each of these sites was provided by the USAF Environmental Technical Applications Center using data from their nearest reporting station (see Table XII). Unfortunately the proximity of the weather station and GEODSS site was not always as close as desired. Thus, the data for the GEODSS site at Mount Haleakala, Hawaii, is not as accurate as desired. This GEODSS site is 3000 meters above sea level whereas the weather station is near sea level. Nevertheless, the sky cover probabilities for this site still indicates predominately clear skies. Also, as indicated in the earlier part of this chapter, LOWTRAN (Ref 27) was used to assess the atmospheric transmittance at sea level and at 23 kilometers above sea level. As a result, the SIGHT subroutine was modified to score a line of sight with a zenith angle of greater than 70 degrees as 0.0 for ground-based sensors, and thus not a clear line of sight. As indicated in the first part of this chapter, the transmittance at zenith angles above 70 degrees tends to drop off rapidly.

The capabilities of the GEODSS system were characterized in the following way. First, the ability of the system to detect each target type in a 24 hour tracking period was determined. A separate program run was used to determine the capability of the GEODSS system to track each target type, and the results of these runs were used to set the mission inputs for each target type in all of the subsequent runs.

60

TABLE XI

Locations of GEODSS sites

Site	Name	Latitude	Longitude
1	Faro, Portugal	37.00N	7.92W
2	White Sands Missile Range, New Mexico	33.82N	106.66W
3	Mount Haleakala, Hawaii, AFB	20.71N	156.26W
4	Taeger, Korea	35.74N	231.39W
5	Diego Garcia	7.20S	287.75W

TABLE XII

Locations of Weather Stations

Site	Name	Latitude	Longitude
1	not substituted		
2	Holloman AFB, New Mexico	32.87	106.10
3	Kahuli, Hawaii	20.78	15.47
4	Taeger ARTCC, Korea	35.74	231.38
5	not substituted		

Next, the ability of the GEODSS system to track all four target types simultaneously was evaluated. The average annual ability of the GEODSS system to track the target system was estimated using the average annual sky cover probabilities with the position of the sun with respect to its latitudinal position over the earth randomly chosen. The impact of the seasonal variation of the sun's position and weather patterns was estimated in separate program runs using the sky cover probabilities at the winter solstice (month of December) and at the summer solstice (month of June) with the sun at its appropriate latitudinal position. In addition, the extent to which the cloud cover diminishes the effectiveness of the GEODSS system was estimated by setting the sky cover probabilities all to 1.0. the GEODSS system experiments required eight computer runs.

The capabilities of the air-based sensor were modeled around those of the GEODSS sensor. Like the GEODSS sensors, tracks for the air base sensors were limited to those with a line of sight less than or equal to 70 degrees to the zenith. This cutoff was again chosen since the intensity of the night sky background can be significantly larger beyond this point (Ref 19:19-23). For example, night airglow emission increases with increasing zenith angle because the telescope looks through a larger emitting air mass.

The first step in evaluating the air-based system was to use EOBASE to choose an air-based system sufficient to match or better the performance of the GEODSS system in tracking all four target types simultaneously. This system was chosen with the longitudinal position of the sun randomly chosen. Then this system was evaluated in

separate computer runs with the sun in its winter and summer solstice
positions. Next EOBASE was used to choose a sensor system with five
air-based sensors as opposed to five GEODSS sensors. Then the ability
of this system to track the target system was evaluated to determine
how well five air-based sensors could track the target system as
opposed to five GEODSS sensors.

Results and Discussion

As indicated in the previous section, the first step in
characterizing the ability of the GEODSS system to track the target
system was to assess its ability to track each individual target type.
The purpose of this step was to determine the maximum percentage of
each target type that the GEODSS system could reasonably be expected
to track in a 24-hour period. So, the GEODSS system was run against
each target type with the tracking negation percentage set to
100 percent, the mission time to 1440 minutes, and the tracking
priority to 1. The initialization and sensor type inputs used for
these experiments and the remaining GEODSS characterizations are shown
in Table XIII unless otherwise specified. Also, the average annual
sky cover probabilities were used unless otherwise indicated.

The ability of the GEODSS system to track the first target type,
a satellite in the highly eccentric Molynia orbit, was never
100 percent in a 24-hour period. Apparently, the apogee of at least
one target satellite of this type is always oriented toward the sun
where it could not be sighted by any earth based sensor. Note that if
the angle between the sun and the sensor (with the target at the
vertex) is greater than 90 degrees, very little sunlight, if any, is

63

TABLE XIII

Basic Initialization and Sensor Inputs
for GEODSS System Simulation

Initialization

SEED	151	- -
JCOUNT	0	- -
NOWT	1	- -
ICOUNT	40	- -
DT	10.	minutes
P	.5	- -
INPUT	5	- -
INPUT 2	0	- -
SUNTYP	4	- -

Sensor

Mode	1.0	- -
Type	1.0	- -
Cutoff	16.0	visual magnitudes
Altitude	0.0	kilometers
Cycle time	120.0	seconds
Dwell time	0.0	seconds

reflected by the target to the sensor by an earth oriented cylinder. This problem is not remedied by placing a target (of type 1) with the apogee of its orbit oriented toward the sun in another part of its orbit because the very small portion of its orbit which is not oriented to the sun is mostly in the earth's shadow where there is no sunlight to reflect. The perigee of target type one is only 300 kilometers high. Nevertheless, since the longitude of the ascending mode of this target type is always 120 degrees apart, the GEODSS system can track at least two targets. In only three cases out of 40 trials was only one target tracked, and two targets were tracked in all other cases. As a result the GEODSS system could be expected to track two

targets of this type, and so a tracking percentage of 65 percent was used in all subsequent runs.

Target type 2 produced similar results, and it is also in a high eccentric orbit. However, the longitude of the ascending modes for this target type are separated by only 90 degrees. So, in this case two targets could be oriented toward the sun. In 10 of 40 trials only two targets were tracked. In the remaining trials, three targets were tracked. So, the mission negation percentage was again set to 65 percent in all subsequent runs.

Target types 3 and 4 produced similar results because both use geosynchronous orbits. With target type 3, 28 out of 40 trials resulted in all targets tracked; and with target type 4, 27 out of 40 trials resulted in all targets tracked. Thus, in both cases, the mission negation percentage was set to 100 percent in all subsequent computer runs.

The next step in evaluating the GEODSS system was to test its ability to track all the target types simultaneously. The results of these runs are shown in Table XIV. These four experiments suggest that cloud cover has an important effect in reducing the effectiveness of the GEODSS system. The number of successful runs increases quite significantly when the sky cover probabilities are all set to 1.0. The latitudinal position of the sun is also important. All but one of the GEODSS sites is in the northern hemisphere, and Diego Garcia, the site in the southern hemisphere, is very close to the equator. Thus, the latitudinal position of the sun can significantly alter the number of hours the sites spend in daylight and are therefore not functional.

65

TABLE XIV

Results of GEODSS System Encounters with the
Four Target Type Target System

Experiment	Number of Successful Trials
1. Average Environment	15
- Annual sky cover probabilities	
- Random sun	
2. Winter Solstice Environment	26
- December sky cover probabilities	
- Sun at winter solstice	
3. Summer Solstice Environment	12
- June sky cover probabilities	
- Sun at summer solstice	
4. Cloudless environment	34
- Sky cover probabilities all set to 1.0	
- Random sun	

* Out of 40 trials.

This effect is important because the sun spends considerable time near its latitudinal extremes, hence the name solstice. The seasonal variation in cloud cover may also be important. Although the sites are widely dispersed, with one exception, they all experience the same seasons at the same time. Since the unconditional probability of less than or equal to 3/8 sky cover varies with the time of year (see Table XV), the probability of good weather at the sites may vary as a whole

TABLE XV

Average Nighttime Probability of Less than or Equal to 3/8 Sky Cover

Site	Annual	June	December
1	.70	.75	.55
2	.70	.78	.73
3	.64	.65	.66
4	.52	.72	.35
5	.33	.38	.34

Note: These nighttime probabilities are defined by observations taken at the weather stations between 2,000 hours and 0400 hours local time.

so that the system performance may be dependent upon the time of year. Table XV indicates that better weather occurs in June at most of the GEODSS sites than in December.

The air-based system was chosen using the inputs shown in Table XVI. This resulted in the selection of three sensors. The sensors were located on lines of longitude separated by 120 degrees. Two sensors were located 10 degrees north, and one sensor was located 10 degrees south.

This system was able to track the target system (all 4 target types) 27 out of 40 times during a 24-hour period. In all cases the target satellites in geosynchronous orbits were target within 24 hours. The satellites in subsynchronous orbits limited the mission success rate. The system was also evaluated with the sun at the winter and summer solstices. With the sun in the winter position, 40 out of 40 trials were successful in meeting the mission requirements. Twenty-five trials were successes with sun in the summer position.

These runs strongly indicate that if all other aspects of the air- and ground-based modes are equal, that is sensor performance and reliability, three air-based sensors can match or exceed the performance of the GEODSS system which includes five sensors.

EOBASE was also used to choose an air-based system composed of five sensors. The same inputs shown in Table XVI were used except the sensor system was required to track the target system in 1200 minutes with a probability of .99. The program was allowed to run until it ran out of CPU time. At this point five sensors had been chosen.

TABLE XVI

Inputs Used To Choose The Air Based System

Initialization

SEED	151	– –
JCOUNT	40	– –
NOWT	1	– –
ICOUNT	40	– –
DT	10.	minutes
P	.375	– –
INPUT	0	– –
INPUT 2	0	– –
SUNTYP	4	– –

Sensor

Mode	1.0	– –
Type	1.0	– –
Cutoff	10.0	visual magnitudes
Altitude	23.0	kilometers
Cycle time	120.0	seconds
Dwell time	0.0	seconds

Note: The same target selection and mission inputs used to characterize the GEODSS system were used to select the air-based system.

These five sensors were located as shown in Table XVII. This
system was able to track the target system 37 out of 40 times in 24
hours. The target satellite located in geosynchronous orbit were
always tracked within 24 hours. The performance of this system was
about as good as the GEODSS system in the absence of cloud cover.

The experiments with the air-based sensors indicate air basing
could significantly increase the frequency deep space satellites are
tracked. Three air-based sensors could conceivably match or surpass
the performance of the GEODSS system. In addition, a reliable air-
based system could assure that all geosynchronous satellites would be
tracked within any 24-hour period. This comparative analysis of the
GEODSS system with a system of hypothetical air-based sensors was
conducted in two phases. First, the capabilities of the GEODSS system
to track all four target types was determined, and the position of the
sun and cloud cover conditions were varied so that their effect upon
the capabilities of the GEODSS system could be estimated. The results
of these experiments showed that it was possible for an earth based
sensor to consistently track only two of the three type 1 targets and
three of the four type 4 targets in a 24-hour period. All of the type
1 and type 4 targets could be track in a 24-hour period. These
experiments also showed that cloud cover significantly reduces the
effectiveness of the GEODSS system and that the latitudinal position
of the sun causes the effectiveness of the GEODSS system to vary
considerably. Next, a system of air-based sensors was chosen which
could match the GEODSS system's capability to track the target system.

TABLE XVII

Five Sensor Air-Based System

Sensor	Latitude	Relative Longitude* (degrees)
1	1.4039	0
2	1.4039	144
3	2.1041	216
4	0.6930	288
5	1.5708	72

Note: The longitude of the first sensor is randomly chosen and the remaining sensors are placed relative to it

Only three air-based sensors were needed. When a system of five air-based sensors were chosen, it was found that this system could be tracked within 24 hours nearly 100 percent of the time.

Unfortunately it cannot be stated without reservation that these air-based systems would perform as well as indicated. As noted in Chapter III under "Sensor Placement," submodel TRACK does not consider geographic features as part of the sensor placement process. Since it is possible that the desired system configuration might not be achievable in the real world, in practice these air-based systems might not perform as well as indicated by the model.

In the next chapter, the information contained in this study will be summarized. Then some conclusions will be presented. Finally, this work will close with some recommendations for further study.

V Conclusion

The primary purpose of this thesis has been to evaluate the possible benefits of an air-based system of electro-optical telescopes. As a prerequisite, some effort has been made to show the need for and the plausibility of such a system.

Summary

The presence of the atmosphere is a serious hindrance to a ground-based astronomical telescope. Because of this, the satellite tracking telescopes of the Air Force's SPADATS network tend to be located at remote sites at high elevation. The use of air-based sensors has been suggested as a possible solution for this problem. This approach has already been adopted by astronomers who use balloons and airplanes to carry their infrared telescopes into the stratosphere.

Several efforts are currently under way to develop a high altitude airship which can remain on station for extended periods of time. The Air Force's program has already demonstrated the feasibility of this kind of vehicle with the launch of High Platform II in May of 1970, and the Navy, as demonstrated by its Hi Spot, is seriously considering the high altitude airship for operational use. On the other hand, NASA is studying the value of this kind of airship for commercial use. NASA has purposed the HAPP concept which utilizes a microwave transmitter to power a high

73

concept which utilizes a microwave transmitter to power a high altitude airship or perhaps a high altitude airplane.

The program EOBASE has been developed to estimate the value of a high altitude platform for satellite tracking. The program can be used to assess the gain in performance conferred by the airship's high operating altitude and flexibility in site selection. The program simulates getting the first track on each satellite of a system of deep space satellites using either a system of user input sensors or a system of sensors selected by EOBASE.

The EOBASE program has been used here in a comparative analysis of the GEODSS system with a hypothetical system of air-based sensors. This analysis was conducted in two phases. First, the EOBASE program was used to assess the capability of the GEODSS system to track four target types, both individually and collectively. This analysis showed that the affect of weather is quite detrimental to the GEODSS system, and that the changing position of the sun can cause its performance to vary considerably. Second, EOBASE was used to choose an air-based sensor system based upon its ability to track all four target types simultaneously at least as well or better than the GEODSS system. Only three air-based sensors were needed to match the performance of the GEODSS system. The performance of this system was also found to be dependent upon the position of the sun. EOBASE was also used to select an air-based system of five air sensors. This system was able to track the target system within 24 hours nearly 100 percent of the time.

Conclusions

While the results of this study with EOBASE are not sufficient grounds for launching a program to develop a system of air-based satellite tracking telescopes, they do demonstrate that such a system may have value. The possibility that three air-based sensors could match the performance of the GEODSS system means that there could be possible cost savings promising air-based sensors instead of ground-based sensors. Also, the air-based sensor could have greater value in the early warning role than the GEODSS system. The air-based system is consistently able to track all the satellites in geosynchronous orbit in less than 24 hours because unlike a ground-based system, it is unaffected by weather. However, it should be emphasized that because of the dearth of basing restrictions in the sensor placement process in practice, the air-based system may not perform quite as well as indicated.

Based upon the results of their study, the concept of using air-based satellite surveillance telescopes warrants an engineering feasibility study. This study is needed to determine if the required sensitivity can be obtained with a sensor light enough to be carried by a high altitude airship or perhaps a high altitude airplane. Also, this study is needed to establish a basis for a cost analysis.

Recommendations

Further refinements of the results obtained with EOBASE could be useful. Following is a list of recommendations which should lead to an improved understanding of the problems involved in choosing the proper basing mode.

1. Allow the user to input the target satellite orbital and shape parameters of his choice.

2. Allow different negation times for each target type.

3. Revise subroutine VISIBLE to include the effect of atmospheric transmittance.

4. Include basing restrictions in the sensor placement algorithm.

Bibliography

1. E40BF2031-001/E4A0F27650-007. Space Systems Operations. Study Guide. Keesler AFB, Mississippi: Keesler Technical Training Center, July 1, 1981.

2. Luke, Charles A. Design Study for Airborne Electro-optical Surveillance Experimentation. Final Technical Report. Wright-Patterson AFB, Ohio: Air Force Avionics Laboratory, October 1967. (AD 386 262)

3. Carlson, Donald J., Shanley, Thomas J. B., and McClarty, John R. High-Altitude Infrared Detection Techniques. Final Technical Report. Wright-Patterson AFB, Ohio: Air Force Avionics Laboratory, April 1972. (AD 520 093)

4. "Telescope in C-141 to Gather IR Data," Aviation Week & Space Technology, 97(21): 71-72 (November 20, 1972).

5. Hudson, Richard D. Infrared System Engineering. New York: John Wiley & Sons, 1969.

6. Fazio, G. G. "A 102-cm Balloon Borne Telescope for Far-Infrared Astronomy," Optical Engineering, 16(6): 551-557 (December 1977).

7. Boggess, N. W. "Infrared Instrumentation on NASA Airborne Observatories," Optical Engineering, 16(6): 528-532 (December 1977).

8. Office of the Assistance for Study Support. Spacetrack Augmentation Tradeoff Study, Annex B- Augmentation Options. Final Report. Kirtland AFB, New Mexico: DCS/Development Plans, Air Force Systems Command, November 1973. (AD 528 642)

9. Beemer, Jack D., Parsons, Roger R., Rueter, Loren L., Seuferer, Paul A., and Swiden, LaDell R. POBAL-S, The Analysis and Design of a High Altitude Airship. Final Technical Report. Sioux Falls, South Dakota: Raven Industries Inc., February 1975. (AD A012 292)

10. Scales, Stewart H. and McComas, C. B. High Altitude Superpressured Powered Aerostat (HASPA) Demonstration Program. Final Technical Report. Denver, Colorado: Denver Division, Martin Marietta Aerospace, October 1977. (AD B021 939L)

11. Wessel, P. R. and Petrone, F. J. "Special Problems and Capabilities of High Altitude Lighter Than Air Vehicles," Proceedings of the Interagency Workshop on Lighter Than Air Vehicles. 595-603. Cambridge, Massachusetts: Flight Transportation Laboratory, Massachusetts Institute of Technology,, 1975.

12. Greenstone, Reynold. <u>Environmental and Technological Uncertainties Related to the High Altitude Powered Platform (HAPP) Concept</u>. Technical report proposed under Contract No. NASW-2961 for NASA. Silver Spring, Maryland: ORI, Silver Spring, Maryland.

13. Marcy, William L. and Hookway, Ralph O. <u>Propulsion Options for the HI Spot Long Endurance Drone Airships</u>. Final Technical Report. Denver, Colorado: Denver Division, Martin Marietta Aerospace, September 1979. (AD A074 595)

14. Elson, Benjamin M. "Cost Factor Key to Unmanned Vehicles," <u>Aviation Week and Space Technology</u>, 117(8): 65-73 (August 9, 1982).

15. Sinko, James W. "High-Altitude Powered Platform: A Microwave Powered Airship," <u>A Collection of Technical Papers</u>. 212-218. Palo Alto, California: AIAA Lighter-than-Air Conference, New York, New York, July 1979.

16. Kuhner, Mark B. "Application of the High-Altitude Powered Platform (HAPP), "<u>A Collection of Technical Papers</u>. 146-154. Palo Alto, California: AIAA Lighter-than-Air Conference, New York, New York, July 1979.

17. Dutton, Jeffrey L. <u>HELBASE: A Tool for the Analysis of High Energy Laser Development, Deployment, and Operation</u>. Unpublished M.S. Thesis. Wright-Patterson, AFB, Ohio: Air Force Institute of Technology, 1980. (AD A094854)

18. Copeland, William R. <u>A Validation Study of HELBASE: A Tool for the Analysis of Strategic High Energy Laser Weapon System Development and Operation</u>. Unpublished M.S. Thesis. Wright-Patterson AFB, Ohio: Air Force Institute of Technology, December 1981. (AD B067181)

19. AVCO Systems Division. <u>Satellite Photometry</u>. Study Guide. Wilmington, Massachusetts: AVCO Systems Division, January 31, 1977.

20. Wolfe, William L. And Zissis, George J., ed. <u>The Infrared Handbook</u>. Technical Handbook. Arlington, Virginia: Office of Naval Research, Department of the Navy, 1978.

21. Weber, Robert. "The Ground-Based Electro-Optical Detection of Deep-Space Satellites." <u>Applications of Electronic Imaging Systems</u>. SPIE Vol. 143 (1978).

22. Slater, Phillip N. <u>Remote Sensing</u>. Reading, Massachusetts: Addison-Wesley Publishing Company 1980.

23. Strganac, Thomas W. "Wind Study for High Altitude Platform Design," _A Collection of Technical Papers_. 155-161. Palo Alto, California: AIAA Lighter-than-Air Conference, New York, New York, July 1979.

24. Richardson, M. _Plane and Spherical Trigonometry_. New York: The MacMillan Company, 1950.

25. Bate, Roger R., et al. _Fundamentals of Astrodynamics_. New York: Dover Publications Inc., 1971.

26. Kneizys, F. X., et al. _Atmospheric Transmittance/Radiance Computer Code LOWTRAN 5_. Scientific report. Defense Hanscom AFB, Massachusetts: Optical Physics Division, Air Force Geophysics Laboratory, February 21, 1980. (AFGL-TR-80-0067)

27. ADCOM/J3Z. _Alternatives for GEODSS Sites Four and Five_.

28. Lund, Iver A. and Shanklin, Milton D. "Photogrammetrically Determined Cloud-Free Lines-of-Sight Through the Atmosphere," _Journal of Applied Meterology_. 11: 773-782 (August 1972).

29. ----- "Universal Methods for Estimating Probabilities of Cloud-Free Lines-of-Sight Through the Atmosphere," _Journal of Applied Meterology_. 12: 1040-1043 (September 1973).

30. Haley, Charles and Ghelber, Craig. _A Methodology for Validation of Complex Multivariable Military Simulation Models_. Unpublished M.S. Thesis. Wright-Patterson AFB, Ohio: Air Force Institute of Technology, 1980.

31. Shannon, Robert E. _System Simulation--The Art and Science_. Englewood Cliffs, New Jersey: Prentice Hall, Inc. 1975.

32. Otten, David G., et al. "GEODSS Heavenly Chronicles," _Quest_. 3-23 (Autumn 1980).

33. Beatty, J. Kelly. "The GEODSS Difference," Sky and Telescope. 469-473 (May 1982).

34. Mobley, R. E. and Cameron, R. M. "NASA-ARC 36-Inch Airborne Infrared Telescope." Technical report. Moffet Field, California: Ames Research Center, National Aeronautics and Space Administration, June 1972.

APPENDICES

A Use of the Model

The purpose of this section is to acquaint the EOBASE user with the various input possibilities, how to interpret the data, and how to interpret the output. As an aid to explanation, specific examples will be used.

Inputs

All input is free formatted with both integer and real variables. The first input card contains nine inputs. (1) SEED - the random number generator argument (real), (2) JCOUNT - the number of times the targets are placed to calculate sighting efficiencies (integer), (3) NOWT - the number of sensor types choices to be input (integer), (4) ICOUNT - the number of times TRACK is called to build confidence in the selected sensor system (integer), (5) DT - the time increment in TRACK in minutes (real), (6) P - the probability of success required for a given mission (real), (7) INPUT - the number of preselected ground based sensors to be entered (integer), (8) INPUT2 - the number of preselected air and/or space sensors to be entered (integer), and (9) SUNPOS - this number, 1-4, indicates the way the latitudinal position is to be chosen (integer). See Table XVIII.

The next set of data cards contains sensor type information. A separate card is input for each sensor type, and contains all the information given in Table XVIII. All inputs are real.

Table XVIII

Example Scenario

Initialization

SEED	4239.- -
JCOUNT	50 - -
NOWT	1 - -
ICOUNT	10 - -
DT	10. minutes
P	.8 - -
INPUT	0 - -
INPUT 2	0 - -
SUNTYP	4 - -

Sensor

Basing Mode	1.0 - -
Sensor	1.0 - -
Cutoff	16.0 visual magnitudes
Altitude	0. kilometers
Minimum tracking time per cycle	120.0 seconds
Dwell time	0.0 seconds

Mission Data

Target type	4 - -
Target type tracking percentage	100 - -
Mission time	1440 minutes
Target type tracking priority	1 - -

The third set of data cards contain the target types selected and their associated mission data. For each target type selected, a single card with that target type number is included (real), followed by a card containing the mission data for that target type (integer). This is repeated for all target types selected, followed by a "termination" card with a 99. on it (not needed if all target types are selected). Again see Table XVIII.

82

If both INPUT and INPUT2 equal zero, then the above mentioned inputs and the data are entered as shown in Table XIX, otherwise sensor location data is needed.

TABLE XIX

Input Data Format for Preselected Ground Base Sensors

Card #				Contents					
1	4239.	50	1	10	10.	.8	0	0	4
2	.1	1.	.16	0.	120.	0.			
3	4.								
4	4	.93	100	1440	1				
5	99.								

The location of ground-based sensors are entered first in the next set of cards. For each site entered, a single card containing the sensor type, the latitude, longitude, and the altitude (all real) is included in the order just given. The following cards provide the sky cover probabilities (see Table IV in Chapter II for the format). Table XX provides an example input.

Air- and space-based sensors are input next. A card is entered for each sensor and includes the sensor type, the orbital radius or coordinate theta for air-based sensors, the eccentricity, the inclination or coordinate theta, longitude of the ascending mode, and the argument of perigee in the order just given. See Table XXI.

83

TABLE XX

Input Data Format for Preselected Ground Base Sensors

Card #				Contents					
1	1.	.925		6.145	0.				
2	.54	.93	.32	.93	.48	.91	.50	.83	.45
3	.65	.94	.31	.92	.37	.83	.36		
4	.72	.93	.21	.82	.28				
5	.72	.85	.18						
6	.66								

Note: This card represents the GEODSS site at Faro, Portugal located at 37.0 degrees north and 7.917 degrees west. In Card 1, degrees have been converted to radians in the geocentric coordinate referenced system. Cards 2-6 contain the annual sky cover probabilities.

TABLE XXI

Input Data Format for Preselected Air and Space Based Sensor

Card #				Contents	
1	1.	1.5708	0.	1.5708	0.0
2	1.	1000.	0.	1.5708	0.0

Note: Card 1 represents an air-based sensor located on the equator. Card 2 represents a space-based sensor in a in a 90-degree, 1000-kilometer circular orbit. Angular measurements are input in radians.

Output

All sensor types, target types, sensor location, and sky cover probabilities are printed out in an easy to read well documented format. At the start of each TRACK run, the track run is printed, followed by all the sensors selected. When a target satellite is tracked, the target number and sensor number are printed. At the completion of each successful tracking sequence, the total time and the number of targets tracked is printed. If tracking sequence is unsuccessful, only the number of targets tracked is printed. After all the tracking sequences have been completed, the number of successful sequences and the total number of sequences are printed. If the sensor system meets mission requirements, the sensor types and location parameters for all sensors in the sensor system are printed. All output is well documented.

B EOBASE Listing

86

```
C         CAPT RICHARD T. SALMON
          PROGRAM ECBASE(INPUT,OUTPUT)
          DIMENSION SENSOR(6,5),T(14,11),MISSION(4,4),TAROPP(14),
C         SUMEFF(5,410),X(5,410),V(5,410),Z(5,410),XT(14),YT(14),
C         ZT(14), EOSEL(50,6),PATH(5,19),TH(19),SITE(50,4),NU(50),
C         SKYC(50,25)
          INTEGER SUNTYP
          COMMON/AIR/TRNSMT(9),BKGD(9)
          DATA (BKGD(I),I=1,9)/.00236,.0024,.00251,.00272,.00306,.00362,
C         .00467,.00671,.0129/
          DATA (TRNSMT(I),I=1,9)/.9992,.9992,.9992,.9991,.9990,.9988,.9985,
C         .9978,.9958/
C  ***********************************************************
C
C         SEED IS THE RANDOM NUMBER GENERATOR SEED (REAL).
C         JCOUNT IS THE NUMBER OF TIMES THE TARGETS ARE RANDOMLY PLACED TO
C         CALCULATE THE AVERAGE SIGHTING EFFICIENCY FOR EACH POINT ON A
C         SPHERE OF OPERATIONS (INTEGER).
C         NOUT IS THE NUMBER OF SENSOR TYPES (INTEGER).
C         ICOUNT IS THE NUMBER OF TIMES TRACK  IS CALLED TO BUILD CONFIDENCE
C         IN THE SELECTED SENSOR SYSTEM (INTEGER).
C         DT IS THE TIME INCREMENT IN TRACK (REAL).
C         P IS THE PROBABILITY OF SUCESS REQUIRED FOR THE SELECTED SENSOR SYST
C
C         INPUT IS THE NUMBER OF GROUND-BASED SENSORS WHOSE COORDINATES ARE TO
C         ENTERED (INTEGER).
C         INPUT2 IS THE NUMBER OF AIR AND SPACE BASED SENSORS (INTEGER).
C         SUNTYP IS USE TO SELECT TH THETA VALUE OF THE SUN  (INTEGER)
          READX,SEED,JCOUNT,NOUT,ICOUNT,DT,P,INPUT,INPUT2,SUNTYP
          P=P-.001
C
C         THE FOLLOWING IS USED TO CONTROL THE NUMBER OF TIMES SIDEN IS
C         IS RUN BY TRACK TO PROVIDE SIGHTING EFFICIENCIES TO CHOOSE THE
C         THE NEXT BEST SENSOR PATH COMBINATION.
C
          COUNT=ICOUNT
          KCOUNT=JCOUNT/ICOUNT
          IF(KCOUNT.LE.0)KCOUNT=1
          CALL RANSET(SEED)
C  ***********************************************************
C
C         THE FIRST SECTION IS DESIGNED TO ACCEPT USER INPUTS
C         INPUTS ARE READ IN THE FOLLOWING ORDER....
C         SENSOR TYPES
C         TARGET TYPES
C         MISSION DATA
C         SITE LOCATIONS
C         SKYCOVER PROBABILITIES
C         AIR AND SPACED BASED SENSOR PARAMETERS
C  ***********************************************************
C
C         SENSOR INPUTS ARE STORED IN MATRIX SENSOR (6,5)
C
C         UP TO FIVE DIFFERENT SENSOR TYPES MAY BE INPUT, 1 CARD PER SENSOR TY
C         EACH CARD IS FREE FORMATTED, WITH ENTRIES BEING SEPARATED BY COMMAS
C         SPACES.
```
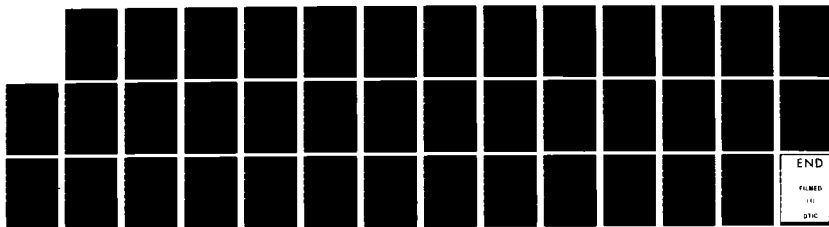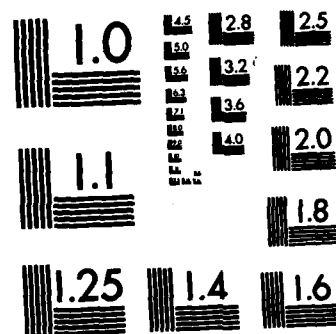
MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

```
C     A "0." MAY BE INPUT WHERE ALLOWED TO ACCEPT THE DEFAULT VALUE.
C     THE VARIABLE ORDER ON EACH CARD IS AS FOLLOWS...
C         MODENO...MODE NUMBER(REAL)..(1-GROUND, 2-AIR, 3-SPACE)(MANDAT
C         TYPE.....SENSOR TYPE(REAL)..(1-VISIBLE, 2-LWIR)
C         CUTOFF...MINIMUM SIGNAL STRENGTH (VISUAL MAGNITUDES)
C                  OR LWIR SENSOR ANGULAR RESOLUTION(RADIANS)
C         ALT......SENSOR ALTITUDE (KILOMETERS)
C                  MODE  1:   0.
C                  MODE  2:   21.3 KM
C                  MODE  3.  (MANDATORY)
C         DELTRM...MINIMUM CYCLE TIME (SEC)
C         DWLTM....LWIR DETECTOR DWELL TIME(SEC)
C     ***********************************************
C
C     TARGET TYPE INPUTS ARE STORED IN MATRIX T(14,7)
C     4 TARGET TYPES  14 TOTAL TARGETS
C         T(I,1) IS TARGET TYPE NUMBER.
C         T(I,2) IS SEMI-MAJOR AXIS OF ORBIT.
C         T(I,3) IS ORBITAL ECCENTRICITY.
C         T(I,4) IS ORBITAL INCLINATION.
C         T(I,5) IS LONGITUDE OF THE ASCENDING NODE.
C         T(I,6) IS ARGUMENT OF PERIGEE.
C         T(I,7) IS MEAN ANOMALY.
C         T(I,8) IS THE PROJECTED AREA OF THE CYLINDER WRT TO THE SENSOR.
C         T(I,9) IS THE REFLECTIVITY OF THE CYLINDER.
C         T(I,10) IS THE PROJECTED AREA OF THE PLATE.
C         T(I,11) IS THE REFLECTIVITY OF THE PLATE.
C     ***********************************************
C
C     MISSION DATA INPUTS ARE STORED IN MATRIX MISSION(4,4) (INTEGER)
C
C     THREE VARIABLES FOR EACH TARGET TYPE ARE ALLOWED
C     A CARD MUST BE INPUT FOR EACH TARGET TYPE SELECTED.
C     AS BEFORE, INPUT 1 CARD FOR EACH TARGET TYPE.
C     CARD FORMAT IS AGAIN FREE FIELD
C         TYPE.....TARGET TYPE (1.,2.,3.,OR 4.) (MANDATORY)
C         TYPNEG...TARGET TYPE NEGATION PERCENTAGE (MANDATORY)
C         TNEG.....TARGET SYSTEM NEGATION TIME (MINUTES) (MANDATORY)
C         NOTE....TNEG MUST BE THE SAME FOR ALL TARGET TYPES SELECTED.
C         PRIFIR...TRACK PRIORITIES (1,2,3,4) (4 THE LOWEST) (MANDATORY)
C     ***********************************************
C
C     SITE LOCATIONS ARE STORED IN SITE(50,4)
C         SITE(I,1)......LATITUDE
C         SITE(I,2)......LONGITUDE
C         SITE(I,3)......ALTITUDE
C         SITE(I,4)......SENSOR TYPE
C     ***********************************************
C
C     SKYCOVER PROBABILITIES ARE STORED IN SKYC(50,25)
C     ARRAY ELEMENTS ARE STORED AS SHOWN BELOW:
C     INITIAL  STATE   INITIAL  +3HR  +6HR  +9HR  +12HR
C     TIME                      PROB
```

```
         1720HR  0-3/8    1         2        4    6    8
         2000HR  4-8/8   10        11       13   15    9
         2300HR  0-3/8   17        18       20   18
         020HR   4-8/8   22        23
         050HR   0-3/8   25

C    USER SELECTED AIR- AND SPACE-BASED SENSORS ARE STORED IN
C    EOSEL(50,6) AS SHOWN LATER IN THE OPTIMIZE SECTION.  THE
C    THE SAME FORMAT IS USED FOR BOTH EOBASE AND USER SELECTED
C    SENSORS.
C
C    ZERO ALL INPUT STORAGE LOCATIONS
C
         DO 5 I=1,6
         DO 7 J=1,6
   7     SENSOR(I,J)=0.
   5     CONTINUE
C        CONTINUE

         DO 90 I=1,14
         DO 91 J=1,11
         T(I,J)=0.
  91     CONTINUE
  90     CONTINUE
C

         DO 175 I=1,4
         DO 174 J=1,4
         MISSION(I,J)=0
 174     CONTINUE
 175     CONTINUE

         DO 797 I=1,50
         DO 797 J=1,25
         SKYC(I,J)=1.
 797     CONTINUE
C

         DO 706 I=1,50
         DO 706 J=1,4
         SITE(I,J)=0.
 706     CONTINUE
C

         DO 342 I=1,50
         DO 341 J=1,6
         EOSEL(I,J)=0.
 341     CONTINUE
 342     CONTINUE
C
C    INPUT SENSOR TYPE SELECTIONS
C
         DO 10 I=1,NOUT
         READ(SENSOR(1U,I),IU=1,6)
         IF(SENSOR(3,I).EQ.0.)SENSOR(3,I)=16.
         IF((SENSOR(4,I).EQ.0.).AND.(SENSOR(1,I).EQ.2.))SENSOR(4,I)=21.3
```

```
10      CONTINUE
C
C       INPUT TARGET TYPE SELECTIONS AND MISSION DATA.
C
        J999=0
        DO 50 J=1,4
        READX,DEL
        IF(DEL.EQ.99.)GO TO 60
        IF(DEL.EQ.2.)GO TO 150
        IF(DEL.EQ.3.)GO TO 155
        IF(DEL.EQ.4.)GO TO 160
C
C       TYPE 1 IS 3 TARGETS IN MOLVNIA ORBITS
C
        DO 110 I=1,3
        T(I,1)=1.
        T(I,2)=2260.
        T(I,3)=.7
        T(I,4)=1.134
        T(I,6)=4.8143
        T(I,8)=.000001
        T(I,9)=.5
        T(I,10)=.000001
        T(I,11)=.50
110     CONTINUE
        READ3,(MISSION(1,IM),IM=1,4)
        J999=J999+3
        GO TO 50
C
C       TYPE 2 IS 4 TARGETS IN SUBSYNCHRONOUS ORBITS
C
150     DO 120 I=4,7
        T(I,1)=2.
        T(I,2)=2260.
        T(I,3)=.7
        T(I,4)=.7854
        T(I,6)=4.5379
        T(I,8)=.000001
        T(I,9)=.5
        T(I,10)=.000001
        T(I,11)=.50
120     CONTINUE
        READ3,(MISSION(2,IM),IM=1,4)
        J999=J999+4
        GO TO 50
C
C       TYPE 3 IS 3 TARGETS IN POLAR GEOSYNCHRONOUS ORBIT
C
155     DO 130 I=8,10
        T(I,1)=3.
        T(I,2)=42164.
        T(I,4)=1.5798
        T(I,8)=.000001
        T(I,9)=.5
        T(I,10)=.000001
        T(I,11)=.50
130     CONTINUE
```

```
      READx,(MISSION(3,IM),IM=1,4)
      J999=J999+3
      GO TO 50
C
C     TYPE 4 IS 4 TARGETS IN EQUATORIAL SYNCHRONOUS ORBITS
160   DO 140 I=11,14
      T(I,1)=4.
      T(I,2)=42164.
      T(I,3)=.00001
      T(I,5)=.5
      T(I,10)=.000001
      T(I,11)=50
140   CONTINUE
      READx,(MISSION(4,IM),IM=1,4)
      J999=J999+4
50    CONTINUE
60    CONTINUE
C
C     INPUT SITE LOCATIONS AND SKY COVER PROBABILITIES
      IF(INPUT .EQ.0)GO TO 794
      DO 793 I=1,INPUT
      READx,(SITE(I,IU),IU=1,4)
      READx,(SKYC(I,IU),IU=1,9)
      READx,(SKYC(I,IU),IU=10,16)
      READx,(SKYC(I,IU),IU=17,21)
      READx,(SKYC(I,IU),IU=22,24)
      READx,SKYC(I,25)
793   CONTINUE
794   CONTINUE
C
C     INPUT AIR AND SPACE BASED SENSOR LOCATION PARAMETERS
      IF (INPUT2.EQ.0)GO TO 787
      J=INPUT +1
      I=INPUT2+INPUT
      DO 788 IN=J,I
      READx,(EOSEL(IN,IU),IU=1,6)
788   CONTINUE
787   CONTINUE
C
C     THIS ENDS THE INPUT SECTION OF EOBASE.
C     xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
C
C     THE FOLLOWING COMMANDS ARE USED AS A VALIDATION OF PROPER INPUTS
      PRINTx,'xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx'
      PRINTx,'xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx'
      PRINTx,'SEED.................',SEED
      PRINTx,'JCOUNT...............',JCOUNT
      PRINTx,'NOUT.................',NOUT
      PRINTx,'ICOUNT...............',ICOUNT
      PRINTx,'DT...................',DT
      PRINTx,'P....................',P
      PRINTx,'INPUT................',INPUT
      PRINTx,'INPUT2...............',INPUT2
      PRINTx,'SUNTYP...............',SUNTYP
```

```fortran
      PRINT*, '*******************************'
      PRINT*, '*******************************'
      PRINT*, ''
      PRINT*, '***** SENSOR TYPES *****'
      PRINT*, ''
      DO 300 I=1,NOUT
      PRINT*, '** SENSOR TYPE ',I,' **'
      PRINT*, ''
      PRINT*, 'MODENO...........',SENSOR(1,I)
      PRINT*, 'TYPE.............',SENSOR(2,I)
      IF(SENSOR(2,I).EQ.2.0)GO TO 867
      PRINT*, 'CUTOFF...........',SENSOR(3,I)
      GO TO 868
867   PRINT*, 'ANGRES...........',SENSOR(3,I)
868   CONTINUE
      PRINT*, 'ALT..............',SENSOR(4,I)
      PRINT*, 'DELTRM...........',SENSOR(5,I)
      PRINT*, 'DULTM............',SENSOR(6,I)
300   CONTINUE
      PRINT*, '*************************************'
      PRINT*, '***** TARGET TYPES SELECTED *****'
      PRINT*, ''
      DO 310 I=1,14
      TAROPP(I)=T(I,1)
      IF(T(I,1).EQ.0.0)GO TO 310
      PRINT*, '** TARGET TYPE ',T(I,1),', TARGET NUMBER ',I,' **'
      PRINT*, ''
      PRINT*, 'SEMI/MAJOR AXIS...........',T(I,2),' KILOMETERS'
      PRINT*, 'ECCENTRICITY..............',T(I,3)
      PRINT*, 'INCLINATION...............',T(I,4),' RADIANS'
      PRINT*, 'ARGUEMENT OF PERIGEE......',T(I,6),' RADIANS'
      PRINT*, ''
310   CONTINUE
      PRINT*, '*****************************'
      PRINT*, '***** MISSION DATA *****'
      PRINT*, ''
      DO 320 I=1,4
      IF((I.EQ.1).AND.(T(1,1).EQ.0.0))GO TO 320
      IF((I.EQ.2).AND.(T(4,1).EQ.0.0))GO TO 320
      IF((I.EQ.3).AND.(T(8,1).EQ.0.0))GO TO 320
      IF((I.EQ.4).AND.(T(11,1).EQ.0.0))GO TO 320
      PRINT*, '** TARGET TYPE ',MISSION(I,1),' **'
      PRINT*, 'TARGET TYPE NEGATION PERCENTAGE ',MISSION(I,2),'%'
      PRINT*, 'TARGET SYSTEM NEGATION TIME.... ',MISSION(I,3),' MINUTES'
      PRINT*, ''
320   CONTINUE
      PRINT*, '*****************************'
      IF(IMPUT.EQ.0)GO TO 701
      PRINT*, '*****SITE LOCATION DATA*****'
      PRINT*, ''
      DO 700 I=1,IMPUT
      PRINT*, 'SITE NUMBER..........',I
```

```
3660-            PRINT*,'LATITUDE.................',SITE(I,1),'RADIANS'
3670-            PRINT*,'LONGITUDE................',SITE(I,2),'RADIANS'
3680-            PRINT*,'ALTITUDE.................',SITE(I,3),'KILOMETERS'
3690-            PRINT*,'SKY COVER PROBABILITIES'
3700-            PRINT 111,(SKYC(I,IU),IU=1,9)
3710-            PRINT 111,(SKYC(I,IU),IU=10,16)
3720-            PRINT 111,(SKYC(I,IU),IU=17,21)
3730-            PRINT 111,(SKYC(I,IU),IU=22,24)
3740-            PRINT 111,SKYC(I,25)
3750-   111      FORMAT(F8.2,F8.2,F8.2,F8.2,F8.2,F8.2,F8.2,F8.2,F8.2)
3760-   790      CONTINUE
3770-   791      CONTINUE
3780-            IF(INPUT2.EQ.0)GO TO 785
3790-            PRINT*,'##### AIR AND SPACE BASED SENSOR LOCATION PARAMETERS #####'
3800-      C
3810-            PRINT*,' '
3820-            I=INPUT2+INPUT
3830-            J=INPUT +1
3840-            DO 786 IOUT=J,I
3850-            PRINT*,'SENSOR TYPE..............',EOSEL(IOUT,1)
3860-            PRINT*,'ORBITAL RADIUS...........',EOSEL(IOUT,2),'KILOMETER'
3870-            PRINT*,'ECCENTRICITY.............',EOSEL(IOUT,3)
3880-            PRINT*,'INCLINATION..............',EOSEL(IOUT,4),'RADIANS'
3890-            PRINT*,'ASCENDING NODE...........',EOSEL(IOUT,5),'RADIANS'
3900-            PRINT*,'ARGUEMENT OF PERIGEE.....',EOSEL(IOUT,6),'RADIANS'
3910-            PRINT*,' '
3920-   786      CONTINUE
3930-   785      CONTINUE
3940-            PRINT*,'##############################################'
3950-            PRINT*,'##############################################'
3960-      C
3970-      C ZERO THE SUREFF MATRIX.
3980-      C
3990-            DO 337 I=1,NOUT
4000-            DO 339 J=1,410
4010-            SUREFF(I,J)=0.
4020-   339      CONTINUE
4030-   337      CONTINUE
4040-      C
4050-            IC=1
4060-            IF((INPUT.GT.0).OR.(INPUT2.GT.0))IC=0
4070-            IF((INPUT.GT.0).OR.(INPUT2.GT.0))GO TO 922
4080-      C CALL SPHERE FOR EACH SENSOR TYPE.
4090-      C
4100-            DO 340 I=1,NOUT
4110-            R=SENSOR(4,I) +6378.145
4120-            CALL SPHERE(R,I,X,V,Z,TH)
4130-   340      CONTINUE
4140-      C
4150-      CC##############################################
4160-      CC##############################################
4170-      C
4180-      C THIS SECTION IS SUB-MODEL 'OPTIMIZE'
4190-      C
4200-      C THE PURPOSES OF 'OPTIMIZE' ARE TO PLACE THE FIRST (OR NEXT) SENSOR I
4210-      C THE 'MOST EFFICIENT' ORBIT OR LATITUDE, AND TO DETERMINE WHEN THE
4220-      C DEPLOYED SENSOR SYSTEM BECOMES ENOUGH TO SATISFY THE MISSION
```

```
C     REQUIREMENTS.
Cxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
C     PLACE THE NEXT SENSOR IN THE 'MOST EFFICIENT' ORBIT OR LATITUDE.
C
C     THERE ARE 37 LATITUDINAL PLACEMENT POSSIBILITIES FOR EACH SENSOR TYP
C       IN BASING MODES 1 OR 2.
C
C     THERE ARE 324 ORBITAL PLACEMENT POSSIBILITIES FOR EACH SENSOR
C       TYPE IN BASING MODE 3.
C
C     CALL SIDENIT,XT,YT,ZT,SENSOR,X,Y,Z,SUREFF, EOSEL,TAROPP,JCOUNT
C     C,NOUT,SUNTYP)
C
C     SO SUREFF NOW CONTAINS VALUES OF THE AVERAGE SIGHTING EFFICIENCY WIT
C     A PRESCRIBED CONFIDENCE INTERVAL.
C
343   CONTINUE
C
      DO 500 I=1,NOUT
C
C     FIND THE 'MOST EFFICIENT' LATITUDE FOR EACH MODE 1 OR 2 SENSOR TYPE.
C     THE ATTRIBUTE OF EFFICIENCY USED IS THE 'PATH AVERAGE TARGET SYST
C     SIGHTING EFFICIENCY', PTHEFF.
C
      PTHEFF=0.
      DO 415 J=1,36
      PTHEFF=PTHEFF+SUREFF(I,J)
415   CONTINUE
      PATH(I,1)=PTHEFF/36.
C
      PTHEFF=0.
      DO 417 J=37,71
      PTHEFF=PTHEFF+SUREFF(I,J)
417   CONTINUE
      PATH(I,2)=PTHEFF/35.
C
      PTHEFF=0.
      DO 419 J=72,105
      PTHEFF=PTHEFF+SUREFF(I,J)
419   CONTINUE
      PATH(I,3)=PTHEFF/34.
C
      PTHEFF=0.
      DO 421 J=106,136
      PTHEFF=PTHEFF+SUREFF(I,J)
421   CONTINUE
      PATH(I,4)=PTHEFF/31.
C
      PTHEFF=0.
      DO 423 J=137,163
      PTHEFF=PTHEFF+SUREFF(I,J)
423   CONTINUE
      PATH(I,5)=PTHEFF/27.
C
      PTHEFF=0.
      DO 425 J=164,185
      PTHEFF=PTHEFF+SUREFF(I,J)
```

94

```fortran
425   CONTINUE
      PATH(I,6)=PTHEFF/23.
C
      PTHEFF=0.
      DO 427 J=187,204
      PTHEFF=PTHEFF+SUMEFF(I,J)
427   CONTINUE
      PATH(I,7)=PTHEFF/18.
C
      PTHEFF=0.
      DO 429 J=205,216
      PTHEFF=PTHEFF+SUMEFF(I,J)
429   CONTINUE
      PATH(I,8)=PTHEFF/12.
C
      PTHEFF=0.
      DO 431 J=217,222
      PTHEFF=PTHEFF+SUMEFF(I,J)
431   CONTINUE
      PATH(I,9)=PTHEFF/6.
C
      PATH(I,10)=SUMEFF(I,223)
C
      PTHEFF=0.
      DO 434 J=224,258
      PTHEFF=PTHEFF+SUMEFF(I,J)
434   CONTINUE
      PATH(I,11)=PTHEFF/35.
C
      PTHEFF=0.
      DO 436 J=259,292
      PTHEFF=PTHEFF+SUMEFF(I,J)
436   CONTINUE
      PATH(I,12)=PTHEFF/34.
C
      PTHEFF=0.
      DO 438 J=293,323
      PTHEFF=PTHEFF+SUMEFF(I,J)
438   CONTINUE
      PATH(I,13)=PTHEFF/31.
C
      PTHEFF=0.
      DO 440 J=324,350
      PTHEFF=PTHEFF+SUMEFF(I,J)
440   CONTINUE
      PATH(I,14)=PTHEFF/27.
C
      PTHEFF=0.
      DO 442 J=351,373
      PTHEFF=PTHEFF+SUMEFF(I,J)
442   CONTINUE
      PATH(I,15)=PTHEFF/23.
C
      PTHEFF=0.
      DO 444 J=374,391
      PTHEFF=PTHEFF+SUMEFF(I,J)
444   CONTINUE
```

```
        PATH(I,16)=PTHEFF/18.
C
        PTHEFF=0.
        DO 446 J=392,403
        PTHEFF=PTHEFF+SUMEFF(I,J)
446     CONTINUE
        PATH(I,17)=PTHEFF/12.
C
        PTHEFF=0.
        DO 448 J=404,409
        PTHEFF=PTHEFF+SUMEFF(I,J)
448     CONTINUE
        PATH(I,18)=PTHEFF/6.
C
        PATH(I,19)=SUMEFF(I,410)
        DO 2 J=1,19
        PRINT2,I,PATH(I,J)
2       PRINT2,
CCC
CCC     THIS COMPLETES THE FINDING OF THE 'PATH EFFICIENCIES' FOR EACH
CCC     SENSOR TYPE OF MODES 1. AND 2.
        IF(SENSOR(1,1).LT.2.5)GO TO 500
CCC
CCC     CALCULATE 'PATH AVERAGE TARGET SYSTEM SIGHTING EFFICIENCY' FOR THE
CCC     VARIOUS ORBITAL INCLINATIONS
CCC
        DO 491 N=2,10
        EFF=0.0
        DO 490 J=2,N
        EFF=EFF+PATH(I,J)
        M=J+9
        EFF=EFF+PATH(I,M)
490     CONTINUE
        PATH(I,N)=(EFF+PATH(I,1))/(((N-1)*2)+1)
        PRINT2,I,PATH(I,N)
491     CONTINUE
500     CONTINUE
CCC
CCC     THE PATH MATRIX NOW CONTAINS 'PATH SIGHTING EFFICIENCY ' VALUES
CCC     FOR ALL POSSIBLE PATHS OF ALL SENSOR TYPES.
CCC
CCC     MODES 1 AND 2 SENSOR TYPES WILL HAVE 19 VALUES IN A ROW.
CCC     HOWEVER, LATITUDES MORE THAN 60 DEGREES FROM THE EQUATOR
CCC     WILL NOT BE CONSIDERED AS POSSIBLE BASING LOCATIONS.
CCC     MODE 3 SENSOR TYPES WILL HAVE 10 VALUES IN A ROW.
CCC
CCC     CHOOSE THE PATH WITH THE MAXIMUM EFFICIENCY.
CCC
CCC     LET IMAX BE THE SENSOR TYPE (INTEGER), AND JMAX THE LATITUDE OR ORBI
        XMAX=0.
        DO 540 I=1,NOUT
        L=10
        IF(SENSOR(I,1).LT.3)L=19
        DO 530 J=1,L
        IF((SENSOR(I,1).LT.2.5).AND.(J.GT.7).AND.(J.LT.11))
```

```
C     PATH(I,J)=0.
      IF((SENSOR(1,I).LT.2.5).AND.(J.GT.16))PATH(I,J)=0.
      IF(PATH(I,J).GT.XMAX)IMAX=I
      IF(PATH(I,J).GT.XMAX)JMAX=J
      IF(PATH(I,J).GT.XMAX)XMAX=PATH(I,J)
550   CONTINUE
540   CONTINUE
      PRINT3,.
      PRINT2,I,J,XMAX,IMAX

C     SO THE SENSOR SELECTED BY OPTIMIZE TO BE ADDED TO THE SENSOR SYSTEM
C     SENSOR IMAX IN LATITUDE OR ORBIT JMAX.
C
C$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
C     THE MATRIX SUMEFF HAS NOW SERVED ITS PURPOSE, AND IS ZEROED.
C
      DO 650 I=1,NOUT
      DO 640 J=1,410
      SUMEFF(I,J)=0.
640   CONTINUE
650   CONTINUE

C     THE PARAMETERS OF THE SELECTED SENSOR ARE STORED IN EOSEL(50 BY 6)
C     USE BY TRACK  AND FOR OUTPUT AS THE FINAL SENSOR SYSTEM.
C     EOSEL(IC,1) IS THE SENSOR TYPE (REAL).
C
      EOSEL(IC,1)=IMAX
C
C     EOSEL(IC,2) IS THE ORBITAL RADIUS (MODE 3), OR THE SPHERICAL COORDI
C     THETA (MODES 1 OR 2).
C
      IF(SENSOR(1,IMAX).EQ.3.) EOSEL(IC,2)=SENSOR( 4,IMAX)+6378.145
      IF(SENSOR(1,IMAX).LT.3.) EOSEL(IC,2)=TH(JMAX)
C
C     EOSEL(IC,3) IS THE ORBITAL ECCENTRICITY, AND IS ZERO.
C
C     EOSEL(IC,4) IS THE ORBITAL INCLINATION
C     OR THE SPHERICAL THETA (MODES 1 AND 2)
C
      RINC=(JMAX-1)*10+5
      EOSEL(IC,4)=(RINC/180.)*3.14159
      IF(JMAX.EQ.1) EOSEL(IC,4)=0.0
      IF(JMAX.EQ.18) EOSEL(IC,4)=1.570796
C
C     EOSEL(IC,5) IS THE LONGITUDE OF THE ASCENDING NODE (RANDOM).
C
C     EOSEL(IC,6) IS THE ARGUEMENT OF PERIGEE, AND IS ZERO.
C
      DO 20 J=1,IC
      NU(J)=0
      DO 30 I=1,IC
      IF(( EOSEL(I,1).EQ. EOSEL(J,1)).AND.( EOSEL(I,4).EQ. EOSEL(J,4)))
C     NU(J)=NU(J)+1
30    CONTINUE
20    CONTINUE
022   CONTINUE
```

```
C       THIS COMPLETES THE STORAGE OF THE SELECTED SENSOR PARAMETERS IN EOS
Cxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
C
C       THIS SECTION OF SUBMODEL OPTIMIZE RUNS TRACK ENOUGH TIMES
C       TO DEVELOP A CONFIDENCE OF .9 THAT THE CURRENT SENSOR SYSTEM (SENSOR
C       SELECTED BY OPTIMIZE AND STORED IN EOSEL) EITHER CAN OR CANNOT
C       MEET THE MISSION REQUIREMENTS SPECIFIED BY THE USER.
C
        SUCESA=0.
        DO 700 II=1,ICOUNT
        PRINT8,.
        PRINT8,..            TRACK RUN NUMBER ",II
        PRINT8,.
        CALL TRACK( MISSION,EOSEL ,T,SENSOR,TAROPP,XT,YT,ZT,J9,IC,NU,NOUT,
     C DT,TB,INPUT,INPUT8,SUNTVP,SITE,SKVC)
        J9=J9-(14-J999)
        IF((INPUT.GT.0).OR.(INPUT2.GT.0))GO TO 888
        IF(J9.LT.J999)CALL SIDEN(T,XT,YT,ZT,SENSOR,X,Y,Z,SUNEFF,EOSEL,
     C TAROPP,KCOUNT,NOUT,SUNTVP)
C
C       J9 IS THE NUMBER OF TARGETS NEGATED DURING THIS RUN OF TRACK.
C
888     PRINT8,.
        PRINT8,J9,' TARGETS TRACKED FOR TRACK RUN NUMBER',II
        PRINT8,.
        PRINT8, "xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx88"
        SUCESS=0.
        IF(J9.EQ.J999)SUCESS=1.
        SUCESA=SUCESA+SUCESS
700     CONTINUE
        PRINT8, .
        PRINT8,SUCESA,' OUT OF ',ICOUNT,' TRACK RUNS WERE SUCCESSFUL'
        PRINT8, "xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx88"
        PRINT8, "xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx88"
        PRINT8, "xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx88"
        SUCESA=SUCESA/COUNT
C
C       IF THIS IS ONLY A SIMULATION RUN, THEN DO NOT GET ANOTHER SENSOR.
C
        IF((INPUT.GT.0).OR.(INPUT2.GT.0))GO TO 1000
C
C       IF THE AVERAGE OF SUCESS IS .GE. TO P, THE CURRENT SENSOR SYSTEM
C       MEETS THE MISSION REQUIREMENTS, AND THE SENSOR SYSTEM MAY BE OUTPUT
C
        IF(SUCESA.GE.P)GO TO 1000
C
C       IF THE AVERAGE OF SUCESS IS .LT. P, ANOTHER SENSOR IS NEEDED.
C
        IC=IC+1
        GO TO 343
1000    CONTINUE
C
C       OUTPUT THE FINAL SENSOR SYSTEM WHICH MEETS MISSION REQUIREMENTS.
C
1015    CONTINUE
```

```
7200:            PRINT*,' '
7210:            PRINT*,'        xxxxx SENSORS SELECTED xxx'
7220:            PRINT*,' '
7230:    C
7240:    C     MSEN IS THE INTEGER SENSOR TYPE.
7250:    C
7260:            IF((INPUT.GT.0).OR.(INPUT2.GT.0))IC=INPUT+INPUT2
7270:            DO 1020 I=1,IC
7280:            PRINT*,'     SENSOR SELECTION NUMBER ',I
7290:            MSEN= EOSEL(I,1)
7300:            PRINT*,'      SENSOR TYPE ',MSEN
7310:            PRINT*,'      MODE NUMBER ',SENSOR(1,MSEN)
7320:            IF(SENSOR(1,MSEN).LT.3.)PRINT*,'      LATITUDE IS ',
7330:    C      EOSEL(I,2)
7340:            IF(SENSOR(1,MSEN).LT.3.)GO TO 1020
7350:            PRINT*,'      ORBITAL RADIUS ',EOSEL(I,2),' KILOMETERS'
7360:            ALT=EOSEL(I,2)-6378.145
7370:            PRINT*,'      ORBITAL ALTITUDE ',ALT,' KILOMETERS'
7380:            PRINT*,'      ORBITAL INCLINATION IS ',EOSEL(I,4)
7390:    1020    CONTINUE
7400:            STOP
7410:            END
```

685

690

695

700

705

```
      SUBROUTINE SPHERE(R,RC,X,Y,Z,TH)
      DIMENSION X(5,410),Y(5,410),Z(5,410),TH(19)
      INTEGER RC

C     PROVIDES 3-D CARTESIAN COORDINATES OF ALL 410 POINTS ON THE
C     SPHERE OF OPERATIONS FOR A SINGLE RADIUS
C     CALL STATEMENT MUST SPECIFY WHICH RADIUS AND ENUMERATOR IS TO BE USE

      TH(1)=1.5708
      TH(2)=1.4039
      TH(3)=1.2359
      TH(4)=1.0374
      TH(5)=.8693
      TH(6)=.6930
      TH(7)=.5236
      TH(8)=.3546
      TH(9)=.1675
      TH(10)=.0
      TH(11)=1.7276
      TH(12)=1.9057
      TH(13)=2.1041
      TH(14)=2.2723
      TH(15)=2.4485
      TH(16)=2.6180
      TH(17)=2.7870
      TH(18)=2.9741
      TH(19)=3.1416

C     POINTS 1 THRU 36
C
      XC=0.
      DO 1 I=1,36
      PHI=XC*6.2831B/36.
      CALL CART(R,RC,TH,PHI,1,1,X,Y,Z)
      XC=XC+1.
 1    CONTINUE

C     POINTS ON LAT. 2 AND 11
C
      XC=0.
      DO 3 I=37,71
      PHI=XC*6.2831B/35.
      CALL CART(R,RC,TH,PHI,I,2,X,Y,Z)
      CALL CART(R,RC,TH,PHI,I+187,11,X,Y,Z)
      XC=XC+1.
 3    CONTINUE

C     POINTS FOR LAT. 3 AND 12
C
      XC=0.
      DO 5 I=72,105
      PHI=XC*6.2831B/34.
      CALL CART(R,RC,TH,PHI,I,3,X,Y,Z)
      CALL CART(R,RC,TH,PHI,I+187,12,X,Y,Z)
      XC=XC+1.
 5    CONTINUE
```

```
C     POINTS FOR LAT. 4 AND 13
C
      XC=0.
      DO 7 I=106,136
      PHI=XC*6.28318/31.
      CALL CART(R,RC,TH,PHI,I,4,X,Y,Z)
      CALL CART(R,RC,TH,PHI,I+187,13,X,Y,Z)
      XC=XC+1.
    7 CONTINUE
C
C     POINTS FOR LAT. 5 AND 14
C
      XC=0.
      DO 9 I=137,163
      PHI=XC*6.28318/27.
      CALL CART(R,RC,TH,PHI,I,5,X,Y,Z)
      CALL CART(R,RC,TH,PHI,I+187,14,X,Y,Z)
      XC=XC+1.
    9 CONTINUE
C
C     POINTS FOR LAT. 6 AND 15
C
      XC=0.
      DO 11 I=164,186
      PHI=XC*6.28318/23.
      CALL CART(R,RC,TH,PHI,I,6,X,Y,Z)
      CALL CART(R,RC,TH,PHI,I+187,15,X,Y,Z)
      XC=XC+1.
   11 CONTINUE
C
C     POINTS FOR LAT. 7 AND 16
C
      XC=0.
      DO 13 I=187,204
      PHI=XC*6.28318/18.
      CALL CART(R,RC,TH,PHI,I,7,X,Y,Z)
      CALL CART(R,RC,TH,PHI,I+187,16,X,Y,Z)
      XC=XC+1.
   13 CONTINUE
C
C     POINTS FOR LAT. 8 AND 17
C
      XC=0.
      DO 15 I=205,216
      PHI=XC*6.28318/18.
      CALL CART(R,RC,TH,PHI,I,8,X,Y,Z)
      CALL CART(R,RC,TH,PHI,I+187,17,X,Y,Z)
      XC=XC+1.
   15 CONTINUE
C
C     POINTS FOR LAT. 9 AND 18
C
      XC=0.
      DO 17 I=217,222
      PHI=XC*6.28318/6.
      CALL CART(R,RC,TH,PHI,I,9,X,Y,Z)
```

```
10170-          CALL CART(R,RC,TH,PHI,1+187,18,X,Y,Z)
10180-          XC=XC+1.
10190-  115     CONTINUE
10200-  17    C
10210-        C POINT FOR LAT. 18
10220-        C
10230-  120     PHI=0.
10240-          CALL CART(R,RC,TH,PHI,223,18,X,Y,Z)
10250-        C
10260-        C POINT FOR LAT. 19
10270-  125     PHI=6.28318
10280-          CALL CART(R,RC,TH,PHI, 410,19,X,Y,Z)
10290-          RETURN
10300-          END
```

```
       SUBROUTINE CART(R,RC,TH,PHI,IX,JX,X,Y,Z)
       DIMENSION TH(19),X(5,410),Y(5,410),Z(5,410)
       INTEGER RC
       X(RC,IX)=R*SIN(TH(JX))*COS(PHI)
       Y(RC,IX)=R*SIN(TH(JX))*SIN(PHI)
       Z(RC,IX)=R*COS(TH(JX))
       RETURN
       END
```

10690*
10700*
10710*
10720*
10730*
10740*
10750*
10760*

1

5

103

```
      SUBROUTINE SIDE(T,XT,YT,ZT,SENSOR,X,Y,Z,SUMEFF, EOSEL,TAROPP,
     CJCOUNT,NOUT,SUNTYP)
      INTEGER SENSNO,PTNO,TGTNO,SLNTYP
      DIMENSION X(5,410),Y(5,410),Z(5,410),T(14,11),XT(14),
     CYT(14),ZT(14),SENSOR(6,5), SUMEFF(5,410), EOSEL(50,6),TAROPP(14)
C
C     THE PURPOSE OF THIS SUB-MODEL IS TO GENERATE THE "TARGET SYSTEM
C     SIGHTING EFFICIENCY" VALUES FOR EACH POINT ON EACH SPHERE OF OPERATI
C     (STORED IN MATRIX SUMEFF)
C
      DO 10 I=1,JCOUNT
C
C     CALL TARGET TO INITIALLY PLACE THE TARGETS
C
      CALL TARGET(T,XT,YT,ZT,TAROPP,SUNTYP,SNXCOS,SNYCOS,SNZCOS,SUNPHI)
C
C     SENSNO- SENSOR TYPE NUMBER
C
      DO 20 SENSNO=1,NOUT
C
C     PTNO-POINT ON SPHERE OF OPERATIONS
C
      DO 30 PTNO=1,410
C
C     TGTNO - TARGET NUMBER BEING LOOKED AT
C
      DO 40 TGTNO=1,14
C
C     IF THE TARGET WAS NOT SELECTED BY THE USER OR WAS SEEN
C               DON'T CALL SIGHT
C
      IF(TAROPP(TGTNO).EQ.0.0)GO TO 40
      CALL SIGHT(SENSNO,TGTNO,SENSOR,T,X(SENSNO,PTNO),
     C Y(SENSNO,PTNO),Z(SENSNO,PTNO),XT(TGTNO),YT(TGTNO),ZT(TGTNO),S,
     C SNXCOS,SNYCOS,SNZCOS,RANGE)
      SUMEFF(SENSNO,PTNO)=SUMEFF(SENSNO,PTNO)+S
40    CONTINUE
30    CONTINUE
20    CONTINUE
10    CONTINUE
      RETURN
      END
```

```
                    SUBROUTINE TARGET (T,XT,YT,ZT,TAROPP,SUNTYP,SNXCOS,SNYCOS,SNZCOS,
                   C SUNPHI)
                    DIMENSION T(14,11),XT(14),YT(14),ZT(14),TAROPP(14)
                    INTEGER SUNTYP

C       THIS SUBROUTINE PLACES THE SUN OVER THE EARTH, AND IT
C       GENERATES CARTESIAN COORDINATES FOR RANDOM POSITIONS OF ALL SELECTED
C       TARGETS

                    PI=ACOS(-1.)
                    TWOPI=2.*PI

C       CALL SUNPOS TO PLACE THE SUN OVER THE EARTH.

                    CALL SUNPOS(SUNTYP,SNXCOS,SNYCOS,SNZCOS,SUNPHI)

C       PLACE THE TARGETS

                    DO 100 I=1,14

C       CHECK WHETHER TARGET HAS BEEN SELECTED

                    IF(TAROPP(I).EQ.0.)GO TO 100

C       FOLLOWING RANDOM SELECTION OF THE TRUE ANOMALY (ETA) IS DONE IN 3 ST
C       STEP 1- A MEAN ANOMALY (XM) IS DRAWN FROM A UNIFORM (0,2PI) DISTR

                    RN=RANF(DUM)
                    XM=RN*TWOPI

C       FOR TARGET TYPE 1, THE MEAN ANOMALIES ARE SEPARATED BY 120 DEGREES.

                    IF(I.EQ.2)XM=T(1,7)*TWOPI/3
                    IF(I.EQ.3)XM=T(2,7)*TWOPI/3

C       FOR TARGET TYPE 2, THE MEAN ANOMALIES ARE SEPARATED BY 90 DEGREES.

                    IF(I.EQ.5)XM=T(4,7)*TWOPI/4
                    IF(I.EQ.6)XM=T(5,7)*TWOPI/4
                    IF(I.EQ.7)XM=T(6,7)*TWOPI/4

C       FOR TARGET TYPE 3, THE MEAN ANOMALIES ARE SEPARATED BY 120 DEGREES.

                    IF(I.EQ.9)XM=T(8,7)*TWOPI/3
                    IF(I.EQ.10)XM=T(9,7)*TWOPI/3

C       FOR TARGET TYPE 4, THE MEAN ANOMALIES ARE SEPARATED BY 90 DEGREES.

                    IF(I.EQ.12)XM=T(11,7) +TWOPI/4
                    IF(I.EQ.13)XM=T(12,7) +TWOPI/4
                    IF(I.EQ.14)XM=T(13,7) +TWOPI/4
                    IF(XM.GT.TWOPI)XM=XM-TWOPI
                    T(I,7)=XM

C       STEP 2- THIS MEAN ANOMALY XM IS THEN TRANSFORMED TO THE ECCENTRI
C       ANOMALY EAN BY A ROOT SOLUTION OF THE TRANSCENDENTAL EQUATION.
```

105

```
C   IF THE TARGET HAS ECCENTRICITY OF 0, THE MEAN ANOMALY, ECCENTRIC ANO
C   AND TRUE ANOMALY ARE THE SAME.
C
      IF(T(I,3).EQ.0.)ETA=XM
      IF(T(I,3).EQ.0.)GO TO 50
C
      E=T(I,3)
      A=XM-E
      B=XM+E
      CALL ROOT(E,XM,A,B,EAN)
C
C   STEP 3- THE TRUE ANOMALY ETA IS THEN CALCULATED USING THE ECCENTR
C   ANOMALY EAN
C
      ETA=ACOS((E-COS(EAN))/(E*COS(EAN)-1.))
50    CONTINUE
C
C   SELECT LONGITUDE OF THE ASCENDING NODE RANDOMLY FOR EACH TARGET TYPE
C
      RINC=I-1.
      RM=RANF(DUM)
      T(I,5)=RM*TLOOP1
      IF((I.GE.2).AND.(I.LE.3))T(I,5)=T(I,5)+2.094*RINC
      IF((I.GE.5).AND.(I.LE.7))T(I,5)=T(4,5)+1.5707*(RINC-3)
      IF((I.GE.9).AND.(I.LE.10))T(I,5)=T(8,5)+2.094*(RINC-7)
      IF(I.GE.11)T(I,5)=0.
C
C   CALCULATE R, THETA, AND PHI FROM ORBITAL PARAMETERS
C
      R=T(I,2)*(1.-T(I,3)**2.)/(1.+T(I,3)*COS(ETA))
      THETA1=ASIN(SIN(T(I,4))*SIN(ETA+T(I,6)))
      THETA=(PI/2.0)-THETA1
      IF(T(I,4).LT..0001)PHIS=ETA+T(I,6)+T(I,5)
      IF(T(I,4).LT..0001)GO TO 70
      ASP=TAN(THETA1)/TAN(T(I,4))
      ACP=COS(ETA+T(I,6))/COS(THETA1)
      PHIS=ATAN2(ASP,ACP)+T(I,5)
C
C   CALCULATE CARTESIAN COORDINATES
C
70    XT(I)=R*SIN(THETA)*COS(PHIS)
      YT(I)=R*SIN(THETA)*SIN(PHIS)
      ZT(I)=R*COS(THETA)
100   CONTINUE
      RETURN
      END
```

```
13300:          SUBROUTINE ROOT(E,XM,A,B,EAN)
13310:    1     F(E,XM,EAN)=EAN-E*SIN(EAN)-XM
13320:          F1=F(E,XM,A)
13330:          IF(F1.GT.-.001)EAN=A
13340:    5     IF(F1.GT.-.001)GO TO 100
13350:          F2=F(E,XM,B)
13360:          IF(F2.LT..001)EAN=B
13370:          IF(F2.LT..001)GO TO 100
13380:          IF((F1.GE.-.01).AND.(F2.LE..01))EAN=(A+B)/2.0
13390:   10     IF((F1.GE.-.01).AND.(F2.LE..01))GO TO 100
13400:   50     C=(A+B)/2.0
13410:          F3=F(E,XM,C)
13420:          IF(F3.GT.0.001)F2=F3
13430:   15     IF(F3.GT.0.001)B=C
13440:          IF(F3.GT.0.001)GO TO 50
13450:          IF(F3.LT.-.001)F1=F3
13460:          IF(F3.LT.-.001)A=C
13470:          IF(F3.LT.-.001)GO TO 50
13480:   20     EAN=C
13490:  100     RETURN
13500:          END
```

107

```
                  SUBROUTINE SIGHT(N,TGTNO,SENSOR,T,XS,VS,ZS,XTS,VTS,ZTS,S,SNXCOS,
                C SNVCOS,SNZCOS,RANGE)
                  DIMENSION T(14,11),SENSOR(6,5)
                  REAL MCDENO
                  REAL KX,KV,KZ ,KTGT,LXTS,LVTS,LZTS,LDOTTS,LDOTS
                  INTEGER TGTNO

       C      *** THE FOLLOWING ARE INPUT VARIABLES TO SIGHT***
       C
       C      N= CURRENT WEAPON NUMBER  (INTEGER)
       C      T= TARGET CHARACTERISTICS MATRIX
       C      TGTNO= CURRENT TARGET NUMBER  (INTEGER)
       C      XS,VS, AND ZS ARE COORDINATES OF SENSOR POINT
       C      XTS,VTS, AND ZTS ARE COORDINATES OF TARGET
       C      SNXCOS, SNVCOS, AND SNZCOS ARE THE DIRECTION COSINES TO THE SUN
       C
       C      ***  THE OUTPUT IS S THE TARGET SIGHTING EFFICIENCY FOR THIS ONE
       C      ON ONE, ONE-TIME SIGHTING ATTEMPT ***
       C      S IS EITHER 0 OR 1.
       C      SUBROUTINE 'SIGHT' IS USED BY BOTH 'SIDEN' AND 'TRACK'
       C
       C      'SIGHT' IS PROVIDED A SENSOR AND ITS INSTANTANEOUS POSITION, AND
       C      THE POSITION OF A SPECIFIC TARGET
       C
       C      THE PURPOSE OF 'SIGHT' IS TO DETERMINE WHETHER THAT TARGET COULD
       C      BE TRACKED BY THAT SENSOR WITH THE GEOMETRY IMPLIED
       C
       C      COMPUTE VECTORXL, VL, ZL FROM THE SENSOR (OR POINT) TO THE TARGET.
       C
                  XL=XTS-XS
                  VL=VTS-VS
                  ZL=ZTS-ZS
       C
       C      COMPUTE RANGE FROM SENSOR OR POINT TO TARGET
       C
                  RANGE=SQRT(XL**2+VL**2+ZL**2)
       C
       C      COMPUTE DIRECTION COSINES OF VECTOR FROM SENSOR OR POINT
       C      TO TARGET
       C
                  XLCOS=XL/RANGE
                  VLCOS=VL/RANGE
                  ZLCOS=ZL/RANGE
       C
       C      COMPUTE DIRECTION COSINES OF VECTOR TO SENSOR OR POINT
       C
                  R=SQRT(XS**2+VS**2+ZS**2)
                  XSCOS=XS/R
                  VSCOS=VS/R
                  ZSCOS=ZS/R
       C
       C      COMPUTE ANGLES COR AND PSI.
       C
                  COSCOR=XLCOS*XSCOS+VLCOS*VSCOS+ZLCOS*ZSCOS
                  COR=ABS(ACOS(COSCOR))
                  COSCOR=ABS(COSCOR)
                  MCDENO=SENSOR(1,N)
```

108

```
C
C     TO TRACK IT.
C
115         CALL VISBLE(SENSOR,N,TGTNO,T,XTS,YTS,ZTS,S,SNXCOS,
           C SNYCOS,SNZCOS,RANGE,XL,YL,ZL)
            RETURN
120   799   S=1.
            RETURN
      300   S=0.0
            RETURN
      100   END
```

14970-
14980-
14990-
15000-
15010-
15020-
15030-
15040-
15050-
15060-

```fortran
      SUBROUTINE VISBLE(SENSOR,N,TGTNO,*,XTS,VTS,ZTS,S,SNXCOS,
     C SNYCOS,SNZCOS,RANGE,XL,YL,ZL)
      DIMENSION SENSOR(6,5),T(14,11)
      REAL IRCYL,IRPLT,MAG
      INTEGER TGTNO

C     THIS SUBROUTINE CALCULATES THE VISUAL MAGNITUDE OF AN EARTH-CENTER
C     STABLE CYLINDER WITH ENDPLATES AND DETERMINES IF THE SENSOR CAN
C     SEE THE SATELLITE.
      AREAC=T(TGTNO,8)
      REFC =T(TGTNO,9)
      AREAP=T(TGTNO,10)
      REFP =T(TGTNO,11)
C     AS SHOWN LATER IN THE OPTIMIZE SECTION.
      CUTOFF=SENSOR(3,N)

C     COMPUTE BETA

      RTGT=ABS(SQRT(XTS**2+YTS**2+ZTS**2))
      TGTSUN=SNXCOS*(-XTS)+SNYCOS*(-YTS)+SNZCOS*(-ZTS)
      BETA=ACOS(TGTSUN/RTGT)

C     COMPUTE ALPHA

      RANGE=ABS(RANGE)
      TGTSEN=(-XL)*(-XTS)+(-YL)*(-YTS)+(-ZL)*(-ZTS)
      ALPHA=ACOS(TGTSEN/(RANGE*RTGT))

C     COMPUTE PHIO

      SENSUN=SNXCOS*(-XL)+SNYCOS*(-YL)+SNZCOS*(-ZL)
      PHIO=ACOS(SENSUN/RANGE)

C     COMPUTE THTA
      THTA=((COS(PHIO)-(COS(ALPHA)*COS(BETA)))/(SIN(ALPHA)*
     C SIN(BETA)))
      IF(ABS(THTA).GT.1.0)GO TO 901
      THTA=ACOS(THTA)
      GO TO 902
901   CONTINUE
      THTA=0.
902   CONTINUE

C     CALCULATE IRRADIANCE OF CYLINDER AND ENDPLATES, IRCYL AND IRPLT.

      IRCYL=REFC*AREAC*SIN(ALPHA)*SIN(BETA)*(SIN(THTA)+(ACOS(-1.0)
     C -THTA)*COS(THTA))/(4.0*(ACOS(-1.0))*RANGE**2)

C     IRPLT=REFP*AREAP*COS(ALPHA)*COS(BETA)/(ACOS(-1.0)*RANGE**2)

C     CALCULATE VISUAL MAGNITUDE OF TARGET AT SENSOR.

      IF(COS(BETA).LE.0.)IRPLT=0.
      IF((IRPLT.GT.0.).OR.(IRCYL.GT.0.))GO TO 866
      S=0.
      RETURN
866   MAG=-26.78-2.5*ALOG10(IRCYL+IRPLT)
```

```
C
C       CHECK IF TARGET IS SEEN
C
16140=      IF(MAG.LE.CUTOFF)S=1.0
16150=      IF(MAG.GT.CUTOFF)S=0.0
16160=      RETURN
16170=      END
16180=
16190=
16200=
```

60

```
        SUBROUTINE SLUIR(N,COM,RANGE,SENSOR,S)

C       THIS SUBROUTINE COMPUTES THE SIGNAL TO NOISE RATIO OF A
C       LWIR SENSOR'S TARGET CURRENT(IT) TO ITS BACKGROUND CURRENT(IB)TO
C       DETERMINE IF THE TARGET CAN BE TRACKED.
C       INPUTS TO THE PROGRAM ARE THE ZENITH ANGLE(COM),THE RANGE
C       (RANGE), THE SENSOR TYPE(N),AND THE SENSOR ARRAY.
C       THE ANGULAR RESOLUTION AND THE DETECTOR DWELL TIME
C       ARE EXTRACTED FROM THE SENSOR ARRAY.

        REAL IT,IB,IRADB,IRADT,LB
        DIMENSION SENSOR(6,5)
        COMMON/AIR/TRNSMT(9),BKGD(9)
        PI=ACOS(-1.)

C       COMPUTE DETECTOR FIELD OF VIEW (SOLID) FROM ANGULAR RESOLU-
C       TION.

        SOLID=((SENSOR(3,N)*PI/180.)**2)*PI/4

C       FIND THE APPROPRIATE VALUES FOR THE ATMOSPHERIC RADIANCE(LB)
C       AND THE ATMOSPHERIC TRANSMITTANCE(TAO) BASED ON THE ZENITH
C       ANGLE.
        DO 10 I=1,9
        ANG=(10.*FLOAT(I)-5)*PI/180.
        IF(ANG.GE.COM)GO TO 10
        LB=BKGD(I)
        TAO=TRNSMT(I)
10      CONTINUE

C       COMPUTE TARGET AND BACKGROUND IRRADIANCES.

        IRADB=SOLID*LB*TAO
        IRADT=(PI*46.5*(1/PI**2)/RANGE**2)*TAO

C       COMPUTE TARGET AND BACKGROUND CURRENTS

        IT=.8*.25*IRADT/2.2E-20
        IB=.8*.25*IRADB/2.2E-20

C       COMPUTE SIGNAL TO NOISE RATIO(STON).

        STON=IT*SQRT(SENSOR(6,N))/SQRT(IT+IB)

C       IF STON GT 6, THEN S = 1.
        IF(STON.LT.6.)S=0.
        RETURN
        END
```

112

```
      SUBROUTINE SUNPOS(SUNTYP,SNXCOS,SNYCOS,SNZCOS,SJ,PHI)

C     THIS SUBROUTINE LOCATES THE SUN ON A RANDOM LONGITUDE AND AT A
C     LATITUDE CHOSEN ACCORDING TO SUNTYP.

C     INTEGER SUNTYP

C     SUNTYP IS USE TO LOCATE THE SUN IN ONE OF THREE POSITIONS
C     1.........ON THE EQUATOR
C     2.........MOST EXTREME NORTHERN LATITUDE
C     3.........MOST EXTREME SOUTHERN LATITUDE
C     4.........RANDOM POSITION

      IF(SUNTYP.EQ.1)THETA=1.5708
      IF(SUNTYP.EQ.2)THETA=1.1694
      IF(SUNTYP.EQ.3)THETA=1.972
      IF(SUNTYP.NE.4)GO TO 747
      RN=RANF(DUM)

C     CHOOSE RANDOM DAY AND FIND ANGLE FROM VERNAL EQUINOX(ANGLE).

      DAY =RN*365.25
      ANGLE=2.*ACOS(-1.)*DAY/365.25
C     DETERMINE LATITUDE OF SUN BASED ON TIME OF YEAR

      THETA=ASIN(SIN(.40)*SIN(ANGLE))
      IF(THETA.GT.0.)THETA=1.5708-THETA
      IF(THETA.LE.0.)THETA=1.5708+THETA
747   CONTINUE

C     CHOOSE RANDOM LONGITUDE

      RN=RANF(DUM)
      PHI=2.0*RN*ACOS(-1.0)
      SUNPHI=PHI

C     CALCULATE DIRECTION COSINES

      SNXCOS=SIN(THETA)*COS(PHI)
      SNYCOS=SIN(THETA)*SIN(PHI)
      SNZCOS=COS(THETA)
      RETURN
      END
```

```
18280-       SUBROUTINE CLOUD(SKYC,I,TIME,S,ICFLAG,SUNPHI)
18290- C
18300- C     SUBROUTINE CLOUD MODELS THE WEATHER OF THE NIGHT SKY.
18310- C     CLOUD IS MODELED AS HAVING A PROBABILITY OF CHANGING
18320- C     EVERY THREE HOURS.
18330- C
18340-       DIMENSION SKYC(50,25),ICFLAG(50),TIME(50,5),BFLAG(50)
18350- C
18360- C     FIND THE POSITIVE ANGULAR DIFF BETWEEN THE LONGITUDAL POSIT-
18370- C     OF THE SUN AND THE POSITION OF THE SENSOR TO DETERMINE THE
18380- C     TIME OF DAY AT THE SENSOR
18390- C
18400-       ADD=0.
18410-       SUNLIN=SUNPHI
18420-       IF(SUNPHI.LE.TIME(I,4))GO TO 949
18430-       ADD=2.*ACOS(-1.)-SUNPHI
18440-       SUNLIN=0.
18450-  949  SENPHI=TIME(I,4)+ADD
18460-       DIFF=SENPHI-SUNLIN
18470- C
18480- C     DETERMINE IF THE SITE MUST BE IN DAYLIGHT.  THEN TARGET NOT
18490- C     SEEN.
18500- C
18510-       IF((DIFF.LT.1.3089969).OR.(DIFF.GT.4.9741884))GO TO 948
18520- C
18530- C     IF FIRST TIME CLOUD COVER HAS BEEN DETERMINED, USE INTIAL
18540- C     SKY COVER PROBABILITIES.
18550- C
18560-       IF(ICFLAG(I).GT.0)GO TO 947
18570- C
18580- C     SET FLAG(ICFLAG) FOR INITIAL TIME CLOUD COVER DETERMINED.
18590- C
18600-       IF(DIFF.GT.1.3089969)ICFLAG(I)=1
18610-       IF(DIFF.GT.2.0943951)ICFLAG(I)=2
18620-       IF(DIFF.GT.2.8797933)ICFLAG(I)=3
18630-       IF(DIFF.GT.3.6651914)ICFLAG(I)=4
18640-       IF(DIFF.GT.4.4505896)ICFLAG(I)=5
18650- C
18660- C     SET TIME TO NEXT WEATHER CHECK (TIME ARRAY ELEMENT FIVE).
18670- C
18680-       TIME(I,5)=.7853982
18690- C
18700- C     FIND INITIAL CLOUD COVER PROBABILITY BASED ON INITIAL TIME.
18710- C
18720-       IF(ICFLAG(I).EQ.1)PROB=SKYC(I,1)
18730-       IF(ICFLAG(I).EQ.2)PROB=SKYC(I,10)
18740-       IF(ICFLAG(I).EQ.3)PROB=SKYC(I,17)
18750-       IF(ICFLAG(I).EQ.4)PROB=SKYC(I,22)
18760-       IF(ICFLAG(I).EQ.5)PROB=SKYC(I,25)
18770-       RN=RANF(DUM)
18780-       IF(RN.GE.PROB)S=0.
18790- C
18800- C     BFLAG CONTAINS FLAG INDICATING CLOUD COVER STATE AT INITIAL
18810- C     TIME.
18820-
```

114

```
      BFLAG(I)=S
      GO TO 946

C     FIND IF TIME FCR NEXT CLOUD COVER CHECK.
C
947   IF(ICFLAG(I).EQ.1)FLAG2=DIFF-1.3089969
      IF(ICFLAG(I).EQ.2)FLAG2=DIFF-2.0843951
      IF(ICFLAG(I).EQ.3)FLAG2=DIFF-2.8797933
      IF(ICFLAG(I).EQ.4)FLAG2=DIFF-3.6651914
      IF(ICFLAG(I).EQ.5)FLAG2=DIFF-4.4505896
      IF(FLAG2.LT.TIME(1,5))GO TO 926

C     FIND APPROPRIATE UNCONDITIONAL CLOUD COVER PROBABILITY.
C
      IFIND=INT(TIME(1,5)/.7853982)
      IF(ICFLAG(I).NE.1)GO TO 945
      IF(IFIND.EQ.1)K=2
      IF(IFIND.EQ.2)K=4
      IF(IFIND.EQ.3)K=6
      IF(IFIND.EQ.4)K=8
      GOTO 928
945   IF(ICFLAG(I).NE.2)GO TO 929
      IF(IFIND.EQ.1)K=11
      IF(IFIND.EQ.2)K=13
      IF(IFIND.EQ.3)K=15
929   IF(ICFLAG(I).NE.3)GO TO 927
      IF(IFIND.EQ.1)K=18
      IF(IFIND.EQ.2)K=20
      GO TO 928
927   K=23
C     CHECK IF THERE IS CLOUD COVER AND ADVANCE WEATHER CHECK TIME
C     BY THREE HOURS.
C
928   IF(BFLAG(I).EQ.0.)K=K+1
      RN=RANF(DUM)
      TIME(1,5)=TIME(1,5)+.7853982
      IF(RN.GT.SKYC(1,K))S=0.

C     STORE PRESENT SKY COVER STATUS IN TIME ARRAY 2.
C
946   TIME(1,2)=S
      GO TO 925
948   ICFLAG(I)=0
      S=0.
      TIME(1,2)=S
      GO TO 925
926   S=TIME(1,2)
925   RETURN
      END
```

115

```fortran
      SUBROUTINE TRACK(MISSION, EOSEL,T,SENSOR,TARCPP,XT,VT,ZT,J9,JU,
     C NU,NCUT,ET,TB,INPUT,INPUT2,SUNTYP,SITE,SKYC)
      DIMENSION EOSEL(50,6),T(14,11),TAROPP(14),TRCTEF(50,4),NU(50),
     C SENSOR(6,5),XU(50),VU(50),ZU(50),TIME(50,5),XT(14),MISSION(4,4),
     C VT(14),ZT(14),N(50), SITE(50,4),SKVC(50,25),PUT(50),ICFLAG(50)
      INTEGER SUNTYP
      DO 15 I=1,50
      ICFLAG(I)=0
15    N(I)=0
C
C  BY OPTIMIZE CAN MEET THE MISSION REQUIREMENTS.
C  THE PURPOSE OF TRACK IS TO DETERMINE IF THE SENSOR SYSTEM SELECTED
C
C  IN ADDITION, TRACK CAN BE USED TO TEST THE EFFECTIVENESS OF A
C  SYSTEM OF PRESELECTED SITES AND SENSORS.
C
C  A 50 BY 5 MATRIX (TIME) IS USED TO STORE THE FOLLOWING VARIABLES...
C
C  SENSOR SELECTION NUMBER.
C  PRESENT SITE SKY COVER STATUS.
C  TAVAIL (TIME UNTIL SENSOR WILL BE AVAILABLE AGAIN).
C  XM (MEAN ANOMALY OR PHI ANGLE).
C  TIME FOR NEXT CLOUD COVER CHECK AT FIXED GROUND SITES.
C
C  THE SENSOR SELECTIONS ARE TAKEN FROM THE EOSEL MATRIX GENERATED BY
C  OPTIMIZE.
C
C  ZERO THE TIME MATRIX.
C
      PI=ACOS(-1.)
      DO 10 I=1,50
      DO 5 J=1,5
      TIME(I,J)=0.
5     CONTINUE
10    CONTINUE
C
C  ENTER SITE DATA INTO TIME AND EOSEL ARRAYS IF INPUT .GT. ZERO
C  ALSO COMPUTE XU,VU, AND ZU SENSOR COORDINATES.
C
      IF(INPUT.LE.0)GO TO 944
      DO 943 I=1,INPUT
      TIME(I,4)=SITE(I,2)
      EOSEL(I,1)=SITE(I,4)
      EOSEL(I,2)=SITE(I,1)
      REARTH=6378.145
      R=REARTH+SITE(I,3)
      THETA=EOSEL(I,2)
      PHIS=TIME(I,4)
      XU(I)=R*SIN(THETA)*COS(PHIS)
      VU(I)=R*SIN(THETA)*SIN(PHIS)
      ZU(I)=R*COS(THETA)
943   CONTINUE
944   CONTINUE
C
C  THE TARGETS AVAILABLE ARE REGISTERED IN MATRIX TAROPP (TARGET OPPORT
```

```
C     TAROPP MATRIX IS THE FIRST COLUMN OF THE T MATRIX.
C
C     GENERATE THE TAROPP MATRIX.
      DO 30 I=1,14
      TAROPP(I)=T(I,1)
30    CONTINUE
C     CALL SUBROUTINE TARGET TO INITIALLY PLACE THE SUN AND THE
C     AND THE TARGETS.
C
      CALL TARGET(T,XT,YT,ZT,TAROPP,SUNTYP,SNXCOS,SNYCOS,SNZCOS,SUNPHI)
C
C     BEGIN PROCESS TO MAKE REMAINING SENSOR PLACEMENTS
C
      I=INPUT+1
      J=INPUT2+JU
C
C     CALCULATE NU MATRIX FOR PRESELECTED SPACE AND AIR BASED SENSORS.
C
      IF(INPUT2.LE.0)GO TO 940
      DO 942 K=1,J
      NU(K)=0
      DO 941 L=1,J
      IF((EOSEL(K,1).EQ.EOSEL(L,1)).AND.(EOSEL(K,4).EQ.EOSEL(L,4)))NU(K)
C     = NU(K)+1
941   CONTINUE
942   CONTINUE
940   CONTINUE
C
C     PLACE AIR-BASED SENSORS AND GROUND-BASED SENSORS WHICH ARE
C     NOT FIXED-POSITIONED.
C
      IF((INPUT.GT.0).AND.(INPUT2.EQ.0))GO TO 891
C
C     FIND THE NUMBER OF SENSORS INVOLVED(IONGRD) SO THE
C     SPACING(APART) CAN BE DETERMINED, AND A LONGITUDE(PUT ARRAY)
C     CAN BE DESIGNATED FOR EACH OF THESE SENSORS.
C
      IONGRD=0
      DO 801 K=1,J
      MSEN=EOSEL(K,1)
      IF(SENSOR(1,MSEN).LT.2.5)IONGRD=IONGRD+1
801   CONTINUE
      RM=RANF(DUM)
      APART=2.*ACOS(-1.)/IONGRD
      PUT(1)=2.*ACOS(-1.)*RAN
      DO 802 K=2,IONGRD
      K2=K-1
      PUT(K)=PUT(K2)+APART
802   CONTINUE
C
C     ARRANGE THE SENSORS STORED IN THE EOSEL ARRAY IN TERMS OF THE
C     GREATEST NUMBER ON SAME LATITUDE.
C
      DO 811 K=1,J
      DO 812 L1=K,J
```

117

```
115         IF(NU(K).GE.NU(L1))GO TO 913
            DO 929 L2=1,6
            HOLD=EOSEL(K,L2)
            EOSEL(K,L2)=EOSEL(L1,L2)
            EOSEL(L1,L2)=HOLD
120   909   CONTINUE
            HOLD=NU(K)
            NU(K)=NU(L1)
            NU(L1)=HOLD
      913   CONTINUE
125   912   CONTINUE
            L3=0
            DO 904 L1=K,J
            IF((EOSEL(K,1).EQ.EOSEL(L1,1)).AND.(EOSEL(K,4).EQ.EOSEL(L1,4))
130   C     .AND.(K.NE.L1))GO TO 908
            GO TO 907
      908   L3=K-1
            DO 905 L2=1,6
            HOLD=EOSEL(L3,L2)
135         EOSEL(L3,L2)=EOSEL(L1,L2)
            EOSEL(L1,L2)=HOLD
      905   CONTINUE
            HOLD=NU(L3)
            NU(L3)=NU(L1)
140         NU(L1)=HOLD
      907   CONTINUE
      904   CONTINUE
      911   CONTINUE
      C
145   C     PLACE SPACE-, AIR-, AND REMAINING GROUND-BASED SENSORS
      C
            K=1
            IPLACE=1
            DO 53 I=K,J
150   C
      C     MSEN IS THE INTEGER SENSOR TYPE.
      C
            MSEN= EOSEL(I,1)
            RN=RANF(DUM)
155         TIME(I,4)=RN*P188.
            IF(N(MSEN).EQ.0)GO TO 56
            M=I-1
      58    NN= EOSEL(M,1)
            IF((NN.EQ.MSEN).AND.( EOSEL(I,4).EQ. EOSEL(M,4)))GO TO 57
160         M=M-1
            IF(M.EQ.0)GO TO 56
            GO TO 58
      C
      C     SPACE BASED SENSORS WITH THE SAME INCLINATION ARE EQUALLY
165   C     AROUND THE SAME ORBIT USING THE NU ARRAY WHICH HOLDS THE NUM-
      C     NUMBER OF SENSORS OF THE SAME TYPE WHICH ARE IN THE SAME
      C
      57    RNJ=NU(I)
            TIME(I,4)=TIME(M,4)+(2.8P1/RNJ)
170         EOSEL(I,5)= EOSEL(M,5)
      56    R=SENSOR(4,MSEN)+878.145
            IF(SENSOR(1,MSEN).LT.8.5)GO TO 56
```

118

```
                        EOSEL(I,5)=RANF(DUM)*P*22.
                        THETA1=ASIN(SIN(EOSEL(I,4))*RSIN(TIME(I,4)+EOSEL(I,6)))
                        THETA=PI/2.-THETA1
                        IF( EOSEL(I,4).GT..001)PHIS=TIME(I,4)+EOSEL(I,6)+EOSEL(I,5)
                        IF( EOSEL(I,4).LT..001)GO TO 51
                        ASP=TAN(THETA1)/TAN(EOSEL(I,4))
                        ACP=COS(TIME(I,4)+EOSEL(I,6))/COS(THETA1)
                        PHIS=ATAN2(ASP,ACP)+EOSEL(I,5)
                        GO TO 51
      50                THETA=EOSEL(I,2)
                        IF(I.EQ.1)GO TO 914
                        ISKIP=IONGRD/NU(I)
                        HOP=FLOAT(IONGRD)/FLOAT(NU(I)))
                        IHOP=INT(HOP)
                        HOP=HOP-FLOAT(IHOP)
                        IF(HOP.GT..5)ISKIP=ISKIP+1
                        IPLACE=IPLACE-ISKIP
                        IF(IPLACE.GT.IONGRD)IPLACE=IPLACE-IONGRD
                        IF(PUT(IPLACE).NE.0.)GO TO 916
      914               IPLACE=IPLACE+1
                        GO TO 914
      916               PHIS=PUT(IPLACE)
                        IF(PHIS.GT.(2.*ACOS(-1.)))PHIS=PHIS-2.*ACOS(-1.)
                        TIME(I,4)=PHIS
                        PUT(IPLACE)=0.
      51                XU(I)=RSIN(THETA)*COS(PHIS)
                        YU(I)=RSIN(THETA)*SIN(PHIS)
                        ZU(I)=RCOS(THETA)
                        PRINT8,'SENSOR SELECTED ',I
                        PRINT8,'THETA ',THETA,' PHIS ',PHIS
                        NUMSEN)=1
      53                CONTINUE
      501               CONTINUE
                        PRINT8,
C
C     START CLOCK AT 0 MINUTES.
                        TB=0.
                        GO TO 11
      40                TB=TB+DT
C==========================================================================
C
C     MOVE THE TARGETS ALONG THEIR ORBITS TO CORRESPOND TO THE 5 MINUTE TI
C     INCREMENT.
                        DO 48 I=1,14
C
C     CHECK WHETHER THE TARGET IS AVAILABLE.
                        IF(TAROPP(I).EQ.0.)GO TO 48
C
C     ADVANCE THE MEAN ANOMALY.
                        XNU=28800.2
                        CUBEA=(TT(I,2).)**3.
```

119

```
C      DELXM IS THE MEAN ANOMALY INCREMENT.
C
       DELXM=SQRT(XMU/CUBEA)*DT*60.
C
C      UPDATE THE MEAN ANOMALY IN MATRIX T.
C
       T(I,7)=T(I,7)+DELXM
       E=T(I,3)
       IF(E.EQ.0.)ETA=T(I,7)
       IF(E.EQ.0.)GO TO 46
       XM=T(I,7)
       A=XM-2.*E
       B=XM+2.*E
       CALL ROOT(E,XM,A,B,EAN)
       ETA=ACOS((E-COS(EAN))/(E*COS(EAN)-1.))
46     CONTINUE
       R=T(I,2)*(1.-T(I,3)*R2.)/(1.+T(I,3)*COS(ETA))
       THETA1=ASIN(SIN(T(I,4))*SIN(ETA+T(I,6)))
       THETA=(PI/2.0)-THETA1
       IF(T(I,4).LT..0001)PHIS=ETA+T(I,6)+T(I,5)
       IF(T(I,4).LT..0001)GO TO 47
       ASP=TAN(THETA1)/TAN(T(I,4))
       ACP=COS(ETA+T(I,6))/COS(THETA1)
       PHIS=ATAN2(ASP,ACP)+T(I,5)
47     XT(I)=R*SIN(THETA)*COS(PHIS)
       YT(I)=R*SIN(THETA)*SIN(PHIS)
       ZT(I)=R*COS(THETA)
48     CONTINUE
C
C      TARGET COORDINATE MATRICES XT, YT, AND ZT ARE NOW UPDATED WITH CURRE
C      TARGET POSITIONS.
C
C**********************************************************
C
C      NOW MOVE THE SENSORS ALONG THEIR ORBITS OR LATITUDES.
C
       J=INPUT+INPUT2+JU
       DO 55 I=1,J
C
C      DO GROUND- AND AIR-BASED SENSORS FIRST.
C
       IF(SENSOR(1,MSEN).EQ.3.)GO TO 68
       TIME(I,4)=TIME(I,4)+DT*.0043033
       IF(TIME(I,4).GT.(2.*ACOS(-1.)))TIME(I,4)=TIME(I,4)-2.*ACOS(-1.)
       IF((INPUT.GT.0.0).AND.(SENSOR(1,MSEN).LT.2.5))GO TO 939
       R=SENSOR(4 ,MSEN)+6378.145
       GO TO 938
939    CONTINUE
       R=REARTH+SITE(I,3)
938    CONTINUE
       THETA=.EOSEL(1,3)
       PHIS=TIME(I,4)
C
C      CALCULATE CARTESIAN COORDINATES FOR THE SENSOR LOCATION AT THE CURRE
C      TIME.
C
       GO TO 54
```

```
52    CONTINUE
C*****************************************************************
C     FOLLOWING SECTION MOVES THE SPACE-BASED SENSORS ALONG THEIR ORBITS.
C
C     ADVANCE THE MEAN ANOMALY.
C
      CUBEA=(EOSEL(I,2))**3.
      DELXM=SQRT(XMU/CUBEA)*DT*860.
C
C     UPDATE THE MEAN ANOMALY.
C
      TIME(I,4)=TIME(I,4)+DELXM
C
C     CALCULATE THE SPHERICAL COORDINATES.
C
      ETA=TIME(I,4)
      R= EOSEL(I,2)
      THETA1=ASIN(SIN(EOSEL(I,4))*SIN(TIME(I,4)+ EOSEL(I,6)))
      THETA=PI/2.-THETA1
      IF( EOSEL(I,4).LT..0001)PHIS=TIME(I,4)+ EOSEL(I,6)+ EOSEL(I,5)
      IF( EOSEL(I,4).LT..0001)GO TO 54
      ASP=TAN(THETA1)/TAN( EOSEL(I,4))
      ACP=COS(TIME(I,4)+ EOSEL(I,6))/COS(THETA1)
      PHIS=ATAN2(ASP,ACP)+ EOSEL(I,5)
C
C     CALCULATE THE CARTESIAN COORDINATES.
C
54    XU(I)=R*SIN(THETA)*COS(PHIS)
      YU(I)=R*SIN(THETA)*SIN(PHIS)
      ZU(I)=R*COS(THETA)
55    CONTINUE
C
C     SO ALL THE USEABLE SENSORS ARE MOVED ALONG THEIR RESPECTIVE PATHS.
C
C*****************************************************************
C
C     ADJUST THE TIME MATRIX ELEMENT TMAIL.
C
      K=INPUT+INPUT3+JU
      DO 70 I=1,K
      TIME(I,3)=TIME(I,3)-DT
      IF(TIME(I,3).LT.0.)TIME(I,3)=0.
70    CONTINUE
11    CONTINUE
C
C     ZERO THE TRCTEF MATRIX.
C
      DO 60 I=1,50
      DO 65 J=1,14
      TRCTEF(I,J)=0.
65    CONTINUE
60    CONTINUE
C*****************************************************************
```

```
C     CALL SIGHT TO BUILD TRCTEF FOR ALL SURVIVING TARGETS OVER ALL
C     CURRENTLY USEABLE SENSORS.
C
  345 M=0
      K=INPUT+INPUT2+JW
      DO 100 I=1,K
C
C     MSEN IS THE INTEGER SENSOR TYPE.
C
  350 MSEN = EOSEL(I,1)
C
C     IF THE ITH SENSOR IS NOT CURRENTLY USEABLE, GO TO THE NEXT SENSOR.
C
  355 IF(TIME(I,3).GT.DT)GO TO 100
C
      DO 90 J=1,14
C
C     IF THE JTH TARGET HAS BEEN TRACKED, GO TO THE NEXT TARGET.
C
  360 IF(TAROPP(J).EQ.0.)GO TO 90
      M=M+1
C
C     CALL CLOUD FOR GROUND-BASED SENSORS.
C
  365 S=1.0
      IF(SENSOR(1,MSEN).EQ.1.)CALL CLOUD(SKYC,I,TIME,S,ICFLAG,SUNPHI)
  370 IF(S.EQ.0.0)GO TO 90
C
C     CALL SIGHT FOR THE JTH TARGET AND THE ITH SENSOR.
C
  375 CALL SIGHT(MSEN,J,SENSOR,T,XU(I),YU(I),ZU(I),XT(J),YT(J),ZT(J),S,
     C SKXCOS,SKYCOS,SKZCOS,RANGE)
C
C     RECORD THE INVERSE OF THE RANGE TO THE TARGET IN TRCTEF OR A ZERO
C     IF THE TARGET IS NOT VISIBLE.
C
  380 TRCTEF(I,J)=S
      IF(S.GT.0.)TRCTEF(I,J)=1./RANGE
   90 CONTINUE
  100 CONTINUE
C
C     TRCTEF NOW CONTAINS ZEROS WHERE A SENSOR CANNOT SEE A TARGET DUE
C     TO ANY OF THE FOLLOWING REASONS........
C
C     SENSOR IS CURRENTLY TRACKING A SATELLITE.
C     TARGET HAS ALREADY BEEN TRACKED.
C     TARGET IS NOT IN LINE-OF-SIGHT OF AN AVAILABLE SENSOR.
C
C     TRCTEF ALSO CONTAINS INVERSE OF THE RANGE TO THE TARGET IN ALL
C     OTHER LOCATIONS.
C
Cxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
C
C     TRACK THE TARGETS WITH THE SENSORS
C
  395 DO 300 IPRIOR=1,4
```

```
         DO 222 J4=I1,I2
         IF(TAROPP(J4).EQ.0.)X3=X3+1.
222      CONTINUE
         PERCNT=(X3/D)*100.
         IF(PERCNT.LT.MISSION(ITYPE,2))GO TO 226
         DO 221 J4=I1,I2
         TAROPP(J4)=0.
221      CONTINUE
226      CONTINUE
C
C        COUNT THE NUMBER OF TARGETS OF ITYPE WHICH HAVE BEEN TRACKED.
C        IF ALL OF THE TARGETS ARE TRACKED, STOP TRACK BEFORE TNEG.
C
         J9=0
         DO 275 KK=1,14
         IF(TAROPP(KK).EQ.0.)J9=J9+1
275      CONTINUE
C
         IF(J9.EQ.14)PRINT3,'TRACK WAS STOPPED AT ',TB,' DUE TO MISSION AC
CCOMPLISHMENT'
         IF(J9.EQ.14)GO TO 1000
290      CONTINUE
300      CONTINUE
C
C        IF TRACK HAS NOT BEEN RUN FOR THE MISSION NEGATION TIME, GO TO 40.
C
         JJJ=1
         DO 400 I=1,4
         IF(TB.LT.MISSION(I,3))GO TO 40
400      CONTINUE
1000     RETURN
         END
```
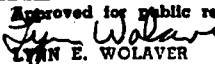
123

VITA

Richard T. Salmon was born at Scott Air Force Base, January 30, 1952. He graduated from Ocean Springs High School, Ocean Springs, Mississippi, in 1970. In 1974 he received a commission in the United States Air Force and a B.S. in Environmental Science from the University of Southern Mississippi, Hattiesburg, Mississippi. In 1979 he received a M.S. in Chemistry from Virginia Commonwealth University, Richmond, Virginia.

After graduation, he worked as an instructor of chemistry at John Tyler Community College, Chester, Virginia. He reentered the Air Force in 1980 and worked as an Orbital Analysis at NORAD's Cheyenne Mountain Complex City, Colorado Springs, Colorado, until he entered the Air Force Institute of Technology in June 1981.

He is married to the former Jo Sylvia Smith of Richmond, Virginia. They have one daughter, JoAnna.

<div align="right">

Permanent address: 302 Teringo-Circle
Ocean Springs, MS 39564

</div>

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFIT/GSO/ /82D-4	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* AN EVALUATION OF THE EFFECTIVENESS OF DEPLOYING ELECTRO-OPTICAL TELESCOPES FOR SATELLITE TRACKING ON HIGH ALTITUDE POWERED PLATFORMS		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Richard T. Salmon Capt		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Air Force Institute of Technology (AFIT-EN) Wright-Patterson AFB, Ohio 45433		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE December 1982
		13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS*(if different from Controlling Office)*		15. SECURITY CLASS. *(of this report)* Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

Approved for public release: IAW AFR 190-17.

LYNN E. WOLAVER
Dean for Research and Professional Development
Air Force Institute of Technology (ATC)
Wright-Patterson AFB OH 45433

19 JAN 193

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Satellite tracking, powered balloons, airships, electro-optical telescope, astronomical telescope, remotely piloted vehicles

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

The purpose of this research was to evaluate the possible benefits of an air based system of electro-optical satellite tracking telescopes. A computerized simulation model was developed to conduct a comparative analysis of a hypothetical system of air based telescopes with the Ground-Based Electro-Optical Deep Space Surveillance (GEODSS) System. The simulation includes a first order optimization process for selecting a satellite surveillance system and a many-on-many engagement model to test the

DD FORM 1473 EDITION OF 1 NOV 65 IS OBSOLETE
1 JAN 73

20.   effectiveness of the surveillance system selected. In addition, the user can input a preselected surveillance system and test its effectiveness.

The user specifies the characteristics of the surveillance system and the basing locations, if they are preselected. Cloud cover data can be entered with preselected ground sites. Target satellites included four sets of representative satellite systems. The user selects the targets, defines the mission time, and determines the percentage of each target system which must be tracked.

Preliminary results indicate that an air based surveillance system with three dispersed telescope platforms could outperform a system of five candidate GEODSS sites.

END

FILMED

3-83

DTIC